A Technical Evaluation of Onsite Wastewater Disposal in South Carolina

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South Carolina Department of Health
and Environmental Control

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Onsite Wastewater
Technical Committee

January 1999

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EXECUTIVE SUMMARY

Onsite Wastewater Disposal Systems (OWDS) are used to provide wastewater treatment where municipal sewerage is not available. Onsite facilities are constructed on individual lots for homes or businesses in unsewered areas. In South Carolina, approximately half of the homes are served by OWDS. Most OWDS are "septic tank systems" which typically consist of a septic tank followed by a subsurface wastewater infiltration system. The South Carolina Department of Health and Environmental Control (DHEC) is responsible for regulatory oversight of OWDS.

Where properly sited, designed, constructed, and operated, OWDS are effective and efficient wastewater treatment facilities. However, because of the large number of OWDS in use, many of which are in high density subdivisions, there are concerns that past and present OWDS practices may be having adverse impacts on public health and the water resources of the state, particularly groundwater. Groundwater is the source of drinking water for approximately 40% of the states population.

Because of these concerns, DHEC formed a technical committee of staff with various technical backgrounds to evaluate OWDS practices in South Carolina and to provide recommendations to improve those practices. The conclusions and recommendations of the committee are as follows:

1. Mottling in the soil column is, in simple terms, the result of a fluctuating water table. This mottling is used to determine the depth to the seasonal high water table. It is recommended that the very first indication of chroma 2 in the soil profile continue to be used as the tool for depicting seasonal high water table (SHWT) conditions. This recommendation recognizes that the gradational changes of chroma in the soil profile from seasonal saturation will also incorporate a common presence of chroma 3 at the first occurrence of chroma 2 in most instances. There are some soils in the coastal plain of South Carolina that are severely drained and do not reflect a significant change in soil chroma but do contain iron (Fe) concretions in the soil profile. These soils should be evaluated for depth to seasonal high water based on the presence of the Fe concretions since these features indicate where the range of rapid water table fluctuation occurs.

2. The contaminants of most concern (pathogens, nitrogen (as nitrate), and phosphorus) behave differently under given environmental conditions. Therefore, any prescriptive standard must be based on a conservative scientific approach. Since the field-based onsite research done in South Carolina has not been able to directly measure impacts from a minimal six-inch separation distance, our recommendations are based on findings from other researchers presented in the literature. Based on this review, the current six-inch offset to SHWT, coupled with a 50-foot setback to receptors, is likely inadequate as a statewide standard. A recommended uniform standard for the entire state must provide protection for the most vulnerable areas of the state. Based on literature reviewed and the trend analysis completed by the committee on downward transport of contaminants (especially bacteria) from

drainfields, an offset of 1.5 feet to the seasonal high water table is recommended, in concert with the current minimum 50 foot lateral setback to potential receptors.

3. Denitrification is the only main process by which nitrate actually can be eliminated as a contaminant under subsurface conditions. Site conditions vary drastically across South Carolina and many areas are not conducive to denitrification. This leaves dilution as a primary process in ameliorating nitrate. Most literature reviewed indicates that nitrate concentrations will be reduced to acceptable levels within 50 feet of the drainfield.

4. Phosphorus, under a majority of situations, will attenuate via soil adsorption. Most of the literature reviewed indicates this occurs within 50 feet. The attenuation of this parameter is dependent upon soil conditions. Adsorption onto very sandy soils has been found to be somewhat weak and temporary. Flushing can occur which may disperse the phosphorus farther from the drainfield area. As with nitrate, in some reviewed literature, it is suggested that as the attenuative capacity of the soil is reached phosphorus migration will continue. It should be noted that most of the studies of phosphorus did not evaluate the concentrations down to 0.01 mg/l which is the level associated with surface water eutrophication.

5. Pathogens are the least understood contaminant and therefore may be of the greatest concern. Migration paths of a hundred feet or more were noted in the literature. This migration appeared to be more prevalent under wet season conditions, i.e., high seasonal water tables and lower temperatures. Viral transport particularly is not well understood. By using fecal coliform bacteria as an indicator of pathogens, and by plotting the data obtained in references, a pattern of reduction of fecal coliform in the groundwater can be established. Because pathogens were not reduced with distance as significantly as nitrogen and phosphorus, fecal coliform counts can be used as the most conservative contaminant of concern (i.e., horizontal setbacks established for fecal coliform reduction will be very protective of nitrogen and phosphorus impacts).

6. The treatment and disposal of onsite wastewater occurs in both the vertical dimension and in the horizontal dimension (in both soils and groundwater). Therefore, establishment of protective lateral offsets to potential receptors cannot be discussed without consideration of the vertical offset to the SHWT. Therefore, two options are provided for consideration:

   - Option 1 is based on the recommended 1.5 foot vertical offset to the SHWT. If the current six inch vertical offset to the SHWT is increased to eighteen inches and is adopted as the new statewide standard, the current lateral offset of 50 feet appears to be much more protective of all receptors under most hydrogeologic conditions expected to be present in South Carolina.

   - Option 2 is based on the observed relationship between fecal coliform reductions and vertical offset to the SHWT. Permitting would be based on a "sliding" scale that incorporates the available treatment in both the vertical (unsaturated zone) and horizontal (groundwater) dimensions. Vertical offsets to the SHWT less than eighteen inches but greater than six inches could be allowed given sufficient lateral offsets to potential receptors.

7. It is recommended that an annual inspection be performed of the OWDS, at which time the depth of sludge is measured, and based upon these results determine if pumping is necessary. Access risers on the septic tank will facilitate inspections. In the absence of an annual inspection, it is recommended that the septic tank be pumped at least every five years. Alternative/innovative OWDS, i.e., systems with electro/mechanical devices, pumps and pressure distribution systems will require more frequent inspections and maintenance to ensure proper operation. There are many options for establishing an inspection and maintenance program, some of which can be accomplished by a governmental entity, e.g., a sewer district, a municipality, or a county, etc.

   Also recommended is increased public awareness and education regarding routine inspections and maintenance of OWDS. The Department could produce media spots for television and radio and develop other educational materials.

8. Malfunctioning OWDS must be repaired so as to eliminate not only a discharge to the surface of the ground, but also to prevent contamination of the groundwater and the environment. This can only be accomplished through an organized system of evaluating malfunctioning OWDS, issuing a permit for the repair and ensuring that the repair is properly made by performing a final inspection of the repair prior to closing or covering the OWDS. Determining the feasibility of an inspection and certification of a properly functioning systems at the “point of sale” is also recommended. Inspections for termites and heating and air conditioning systems are currently conducted when private real-estate is sold; a similar process could be developed for OWDS.

9. At present, there seems to be little information available from other states on operational permit programs. The cost involved, necessary manpower, and other considerations could be partly the reason why many states have not initiated a mandatory operational permit program. Operational permits, at least at the state level, do not appear to be feasible for use in South Carolina at this time.

10. While various alternative and experimental designs for OWDS exist, no one particular design offers a complete panacea for all treatment criteria and pollution concerns. For example, Aerobic Treatment Units (ATUs) provide for excellent treatment of bacteria due to increased aerobic activity in the tank yet have little or no effect on phosphorus (P) and nitrogen (N). Of the systems examined in the literature, sand filters and sphagnum peat filters show the most promise. Not only do they give excellent treatment results, with the exception of some contaminants (primarily P), but require less frequent and less labor intensive maintenance. The selection of an alternative technology as a method of onsite waste disposal and treatment

must be carefully made based on a decision relative to the specific site and sizing criteria, soil types, topography, proximity to environmentally sensitive areas and others.

Maintenance of alternative systems plays a significant role in the ultimate performance of these type systems. The more complex and technologically advanced or innovative a system is, the more that maintenance is a critical factor in the long term success or failure of the system. Maintenance and Operational permits or contracts could be established with local governmental entities (such as water and sewer utility companies) which could guarantee reliable and dependable maintenance on a routine frequency. Another recommendation is to adopt and include in the state's onsite wastewater regulation, provisions which would allow the use of alternative technology systems and at the same time require acceptance of maintenance by a regulated utility.

A key to general acceptance of new and innovative technologies is to find a mechanism whereby both the knowledge and understanding of how various systems function can be gained, as well as an evaluation of their individual strengths and weaknesses. One means of accomplishing this is through the creation or establishment of state, regional or local wastewater training centers. Wastewater training centers are typically designed to display current alternative technologies in the wastewater industry. Centers can be designed for display and training for system technologies or can also include provisions for research and data collection to compare treatment potentials and performance standards with desired results. A cooperative effort involving the research, educational, regulatory, and private sectors and adequate funding are critical to the success of such a program (North Carolina State University has established a model program).

11. A performance-based approach to onsite wastewater management offers the promise of improved onsite system performance and treatment effectiveness, thereby providing greater protection of public health and environmental quality, and, at the same time, greater opportunities for development through the availability of innovative treatment options to overcome site limitations. Therefore, performance-based standards may actually allow development in areas that currently will not be developed using prescriptive standards. Before this approach can be realized, issues related to operation and maintenance must be addressed and resolved. Unless this is done, it is not reasonable to expect that a regulatory onsite wastewater management program based on performance standards can be successfully implemented at this time.

12. In order to minimize the occurrence and impacts of system failures, the Department should:

- Develop and implement a staff standardization program emphasizing site evaluation, system siting and design, and installation inspection procedures.

- Develop training programs for staff and contractors in proper system construction practices and the consequences of improper construction techniques.

- Develop a system failure analysis protocol to define procedures applicable to the inspection, analysis, and repair of failing systems. Provide training programs in failure analysis and repair for staff and contractors.

- Obtain information about system repairs to provide data necessary to assess the need for modifications to current design or siting standards.

- Identify potential resources, technical and financial, which may be developed to establish programs for routine maintenance of onsite systems.

INTRODUCTION

Background

Onsite Wastewater Disposal Systems (OWDS) are used to provide wastewater treatment where municipal sewerage is not available. Onsite facilities are constructed on individual lots for homes or businesses in unsewered areas. In South Carolina, approximately half of the homes are served by OWDS. Most OWDS are "septic tank systems" which typically consist of a septic tank followed by a subsurface wastewater infiltration system. The South Carolina Department of Health and Environmental Control (DHEC) is responsible for regulatory oversight of OWDS.

Where properly sited, designed, constructed, and operated, OWDS are effective and efficient wastewater treatment facilities. However, because of the large number of OWDS in use, many of which are in high density subdivisions, there are concerns that past and present OWDS practices may be having adverse impacts on public health and the water resources of the state, particularly groundwater. Groundwater is the source of drinking water for approximately 40% of the states population.

Because of these concerns, DHEC formed a technical committee of staff with various technical backgrounds to evaluate OWDS practices in South Carolina and to provide recommendations to improve those practices. Members of this committee are: David Baize - Chair (Bureau of Water), Bruce Crawford (Bureau of Water), Lisa Hajjar (Office of Coastal Resource Management), Lewis Bedenbaugh (Central Midlands District EQC), Jack Hafner (Trident Health District), Rod McCormick (Waccamaw Health District), Alex Moss (Environmental Health), and Peter Stone (Bureau of Water).

Objectives and Scope

The Technical Committee was directed to seek out and evaluate the current science on OWDS and to provide recommendations for changes to the existing regulation (R.61-56). To accomplish this goal, the Technical Committee reviewed the reasonably available scientific literature pertaining to the following key issues: offset to seasonal high water table and it's effect; setbacks to receptors (e.g., surface water, water wells); density/cumulative impacts; alternative technologies/advanced treatment; maintenance, repair, and upgrades; operational permits; nitrogen sensitive surface waters; phosphorus sensitive surface waters; bacterial and viral transport; long term acceptance rates (to include loading rates); defining system "failure" and how to measure; evaluation/applicability of performance standards; determining seasonal high water table; groundwater contamination from OWDS; and soil classification. In total, the committee reviewed over 400 references. It should be noted that this document does not represent a comprehensive review of the available literature. Many references obtained were determined to not be directly applicable as the studies were in highly different soil types, limited in scope to the stated areas of concern, etc. References directly used as a basis for the recommendations provided in this report are provided at the end of each section.

One source of information often used by regulatory agencies in establishing OWDS criteria is the Environmental Protection Agencies “Design Manual for Onsite Wastewater Treatment (1). As this guidance document was published in 1980, it was felt that many of the recommendations provided in this document may have been supplanted by the significant amount of research conducted in the last 18 years. We understand that EPA is planning to update this guidance in the next several years.

The recommendations provided in this report are made independent of potential problems associated with implementation, financial considerations, or impacts relative to other regulations. In this way, this committee could evaluate current technical information without bias based on the ultimate practical implementation considerations that must follow. It is recognized, therefore, that the recommendations provided may, or may not, be incorporated into regulation.

What is Wastewater?

Wastewater is mostly water. Other materials make up only a small portion of wastewater, but can be present in large enough quantities to potentially cause detrimental environmental effects or disease. Although there are many indicators of wastewater quality that can be used, potential contaminants from OWDS can be classified into three main categories: pathogens, organic matter, and inorganic matter (4).

Pathogens

Disease-causing bacteria, viruses, and parasites, are present in wastewater (although viruses and parasites may be introduced only sporadically). Collectively, these are the least studied and understood of the three types of contaminants although bacteria are well represented in investigations. Gastroenteritis and other water-related diseases can result from a variety of pathogens in wastewater. Fecal coliforms, which are readily analyzed, are used as a general indicator of the presence of pathogens.

Organic Matter

Organic contaminants enters wastewater in human wastes, paper products, detergents, foods, and other sources. Large amounts of biodegradable materials discharged into surface waters can reduce or deplete the supply of oxygen in the water needed by aquatic life. Toxic organic compounds such as trichlorethylene found in solvents and benzene found in some pesticides and petroleum products are of concern but should not commonly be found in household wastewater.

Inorganic Matter

Inorganic contaminants (e.g., dissolved nutrients, metals, chlorides) of the most concern in wastewater are the nutrients in the form of phosphate and nitrate. Excessive nutrients in receiving water cause algae and other plants to grow quickly where decomposition can deplete oxygen in the water. Excessive nitrate in drinking water may contribute to miscarriages and is the cause of a serious illness in infants called methemoglobinemia or "blue baby syndrome."

How Septic Systems Work

A septic tank system uses natural processes to treat and dispose of the wastewater generated from homes. As wastewater flows into the tank, the heavier solids settle to the bottom to form a sludge layer, and the lighter solids, greases, and oils float to the top to form a scum layer. The clearer liquid wastewater (effluent) from the tank flows into the gravel-filled trenches in the drainfield where it is distributed via perforated pipes and then treated by the natural below-ground environment. Figure 1 shows the components of a typical septic system.

The septic tank provides some biological treatment of the sludge and scum layers that accumulate there. The majority of treatment occurs in the drainfield where the effluent enters the soil and is treated as it percolates to the groundwater. The soil acts mainly as a biological filter and somewhat as a physical filter to remove harmful substances including bacteria and viruses, nitrogen, phosphorus, and other undesirable wastewater constituents remaining in the effluent. The wastewater then ultimately enters the saturated zone or water table. It is in this zone that treated wastewater can travel under natural groundwater flow conditions. Dispersion and dilution of any remaining wastewater constituents occurs in the saturated zone but the mobility of specific dissolved substances varies with each constituent's soil reactivity. The performance of conventional OWDS should be measured by the ability of the system to accept and adequately treat applied wastewater loads within a defined boundary. This boundary is frequently defined to include unsaturated soil below the infiltrative surface of the OWDS down to the water table and a portion of the saturated zone horizontally to a potential receptor (e.g., property line, well, surface water body)(2).

There are a few good rules of thumb, based on experience, that tell us generally when septic systems are most likely to function properly and *minimize* groundwater contamination and subsequent potential impact to receptors (e.g., surface water, wells). The type of soil has an important role in the treatment and disposal of wastewater; for example, soils with a combination of sand, silt and clay will probably work well. If significant clay is present, the percolation of the wastewater is reduced. If the soil is very sandy, wastewater may pass through to the groundwater with less treatment. Also, as wastewater treatment occurs more readily above the water table where the soil is relatively dry and contains more oxygen, the longer the wastewater remains in the soil the higher the ultimate degree of treatment. In addition, septic systems need space to work (i.e., adequate setbacks from potential receptors). Not all microorganisms and chemicals are removed from wastewater as it travels downward through the soil. Even a properly operating system will discharge nutrients (phosphates and nitrates) and perhaps some bacteria or viruses to the top of the groundwater directly beneath the drainfields (3). Finally, if the tank is not pumped regularly to remove the accumulated solids, the tank will fill with sludge and the solids will be washed out into the drainfield. There they will quickly clog the soil and eventually cause the septic system to fail.

The committee would like to emphasize the point above about the function of a properly operating septic system. Wastewater is being treated and disposed by the entire natural system, i.e., soil and in nearby shallow groundwater. It is important for the public to understand that septic systems are designed to promote maximum treatment in the soil but that treatment is likely to continue to occur in the groundwater in many situations. It is not realistic to expect wastewater to be treated to drinking water standards solely within a few inches or feet of vertical flow in the soil. This is too much to expect of a natural system. That is why wells and other receptors must not be located closer than 50 feet of a drainfield and visa versa Therefore, understanding the fate and transport characteristics of the most critical wastewater components is necessary to determine appropriate setbacks to receptors to protect public health and the environment.

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DISCUSSION OF KEY TECHNICAL ISSUES

A. Issue: Establishment/Field Designation of Seasonal High Water Table for Septic Tank Drainfields by a Redoximorphic Feature

Current Approach:

The Department currently utilizes a field verification of soil gleying by hand augering several borings in the proposed area of a septic tank drainfield. Soil gleying of a soil chroma value of ≤ 2 is used for establishing the depth to the seasonal high water table. If the depth to a soil chroma value of ≤ 2 is reached, restrictions (if any) as to trench depth are made. The following terms used in this discussion are defined as follows:

Soil gleying (gleiing) - is a characteristic of periodically waterlogged soil with grey to rusty colored patches (blotches) and sometimes nodules, which represent seasonal saturation by the fluctuations of a shallow water table.

Chroma - soil chroma is the degree of "bleaching" of color due to removal or alteration of minerals. As the chroma value decreases the greyness increases.

Concerns:

Currently SCDHEC requires a 6 inch minimum separation from the bottom of the trench of a septic tank drain line to the seasonal high water table (SHWT). Accurately identifying this depth is crucial when considering that this water level will fluctuate from year to year depending upon the amount of precipitation received in an area. The primary question is whether soil gleying of chroma ≤ 2 is a physical representation of the upper most level of the SHWT. Since oxidation and reduction within the soil profile can take place over a greater distance than 6 inches, a second question is generated. That is, if soil chroma ≤ 2 is not the best indicator of the SHWT, what is, and how accurate is it? Also, to accurately compare methodology (and vertical offsets to groundwater) from state to state, the differences in establishing the SHWT (i.e., first occurrence vs. common and distinct) must be clear.

Available Technical Information:

According to many authors (1- 6), the seasonal high water table soil indicators that depict saturation are represented by gleyed conditions in the soil profile. A gleyed soil profile denotes saturated conditions in which some of the soil minerals have undergone the process of oxidation and reduction. The two mineral components most commonly associated with this process are iron (Fe) and manganese (Mn). Soil gleying is produced when the soil conditions oscillate between aerobic (oxidizing) conditions defined by the presence of free oxygen and anaerobic (reducing) conditions defined by the lack of free oxygen, which correlate to the rise and fall of the water table. The high water level is associated with the winter months of the year. As the water tables rises the ferric iron in the soil column is reduced to ferrous iron and subsequently looses an oxygen which is utilized by soil organisms. Upon the water table receding, the soil is again exposed to free oxygen and the iron again converts to ferric or precipitates onto the soil matrix in the form of mottles or concretions. The color of the soil staining from Fe and Mn can range from yellows to red/reddish browns with varying tones of purple depending on the abundance of available Mn.

Whether the soil gleying is defined as mottles or concretions/nodules it is a result of minerals repeatedly reduced and oxidized as the water table oscillates within a particular interval of the soil column. When the gleying process matures, the zones of the soil column frequently inundated become leached of the Fe and Mn. As significance of this leaching increases the descriptive chroma value for the soil column decreases. It has been generally accepted that to predict the seasonal high water table a mottling of the soil with a chroma value of ≤ 2 or less within a higher chroma matrix is necessary (6,8,9,13,14,16).

Studies have been done to verify that the presence of chroma ≤ 2 within the gleyed soil profile is a consistent indicator of seasonal high conditions of the water table (9,11,13,14). Stone (11) was able to substantiate that a chroma value of 3 correlates more closely to a predictable and repeatable depth to the average seasonal high water table for coastal plain soils of North Carolina. The chroma value of 2 was below the water table 20 to 53% of the time under seasonal high conditions. Even using a soil chroma of 3 the seasonal high water table was still above this level in the soil from 14 to 21% of the time. Vepraskas and Guertal (14) discourage the strict use of morphological indicators because recent alterations in local hydrology will not be accurately reflected in the soil profile.

Hyde (13) referenced some studies where morphological indicators were not representative of the seasonal high water table conditions. Details of these studies are unknown. Other studies referenced by Hyde (13) indicated a chroma value of <3 as a better soil profile indicator of seasonal high water table conditions. Hyde's study spanned a decade (1977-1986) in studying two soil types in Florida and concluded that in one soil type the low chroma values did correlate to the seasonal high water table while the other soil type had a measured seasonal high water table which did not correlate to a low chroma soil. Sawka et al (9) completed a study in Florida with the aid of 99 water wells installed into nine different soil types and monitored for 1 to 5 years. Thirty-seven (37) soil profiles were described, ranging from poorly drained, somewhat poorly drained, to moderately well drained. Seventy-one percent of the soil descriptions denoting mottling had seasonal high water tables above the zone of mottling.

Recommendations

Mottling in the soil column is, in simple terms, the result of a fluctuating water table. This mottling is used to determine the depth to the seasonal high water table. It is recommended that the very first indication of chroma 2 in the soil profile continue to be used as the tool for depicting SHWT conditions. This recommendation recognizes that the gradational changes of chroma in the soil profile from seasonal saturation will also incorporate a common presence of chroma 3 at the first occurrence of chroma 2 in most instances. There are some soils in the coastal plain of South Carolina that are severely drained and do not reflect a significant change in soil chroma but do contain iron (Fe) concretions in the soil profile. These soils should be evaluated for depth to seasonal high water based on the presence of the Fe concretions since these features indicate where the range of rapid water table fluctuation occurs.

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B. Issue: Offset to seasonal high water table

Current Approach:

Section V - Minimum Site Conditions, of R.61-56 requires a minimum six (6)-inch separation distance (or offset) between the bottom of the proposed soil absorption trenches or alternative system and the maximum seasonal high water table (SHWT). The SHWT is determined by the presence of redoxymorphic features (e.g., grey colored mottles) identified in the soil borings during site evaluation.

A conventional soil absorption trench must be at least twenty-three (23) inches deep. Thus it follows that the SHWT must be at or greater than a depth of twenty-nine (29) inches from the soil surface. However, the rules also allow for the use of alternative systems as long as standards have been established for each system. DHEC currently allows several types of shallowly placed alternative system designs that are permitted when the SHWT is higher than 29 inches from the soil surface. More than 75% of all systems installed in the coastal areas of the state are of the shallow-placed design. As with conventional systems, a six-inch separation distance must be met between the bottom of the trenches and the SHWT.

Concern:

The major concern with the six-inch offset standard is whether it allows for the adequate treatment of effluent in what is considered a relatively small vadose or unsaturated zone. This is of particular concern when the groundwater is hydrologically connected to nearby surface water and to other receptors such as drinking water wells. The main contaminants of concern in effluent are nitrogen, phosphorus, bacteria, and viruses. Vertical offset to SHWT is an issue is closely tied to horizontal setback to receptors, as well as other issues that follow. Another concern with the six-inch offset is the mounding effect gravity-fed systems have on the water table which can result in a further reduced depth of unsaturated soil (3, 9).

Discussion of Available Technical Information:

Of the numerous OWDS field-based studies reviewed, the topic of adequate offset to SHWT was seldom listed as a primary research objective. Much of the research was focused on the lateral movement of effluent contaminants with a mention of the offset to SHWT. In many of the papers, the importance of adequate offset was stated; however, the actual offset distances were not included (6, 12, 18, 19, 22). Of those papers that emphasized offset, the results were highly variable, particularly with regard to the various contaminants that were evaluated (e.g., nitrogen, phosphorus, pathogens). The current six-inch offset is often compared to the two-foot offset recommended by EPA in their design manual (1980) previously referenced. It should be noted that only two references provided for EPA's recommended offset; one paper published in 1977 and the other in 1978. EPA's recommendation, therefore, was considered but not given as much weight as the more recent research discussed below.

Research conducted on a coastal barrier island in sandy soils determined that a 30-cm (1 ft.) design separation between the trench bottoms and the SHWT did not consistently provide adequate treatment, and resulted in inconsistent nitrification and incomplete attenuation of bacteria and viruses (7). The 60-cm (2 ft.) design separation used in this study provided adequate microbial treatment but resulted in elevated levels of nitrates. Nitrate levels decreased with distance, suggesting denitrification or dilution was occurring. Phosphorus (P) levels in groundwater were related to pore-water velocity (i.e., the wetter soils retained less P) (7).

Another study done in a coastal watershed found the net transport of nitrogen (N) to be moderately conservative, whereas P was strongly retained by the aquifer. The water table in this study ranged from 1-4 meters (3-13 ft.) deep and the soils were medium to coarse sands. The authors suggested that septic systems may contribute substantially to eutrophication of marine or estuarine ecosystems that are N-limited (24).

Florida researchers determined that a 2-foot separation in fine sand provided treatment better than is typical of secondary wastewater treatment, and equaled that of a 4-foot separation (2). Nitrate levels were high (20 mg/l) at both the 2- and 4-foot separations; however, fecal coliforms were effectively removed (2).

Another Florida study compared treatment of inorganic constituents (no bacterial analyses done) at a sand site and a limestone site, where the offset to water table was from 3-4 feet at the sand site and 3.5-6.5 feet at the limestone site (23). Effluent moved primarily in the vertical direction because of low hydraulic gradients and was diluted or attenuated as it moved downgradient. Effluent was detected more than 20 ft. below the septic tank outlet at the sand site and more than 25 ft. below the outlet at the limestone site. At the sand site, dissolved constituents in effluent were near background concentrations about 50 ft. downgradient. Inorganic indicators of effluent were detected at the limestone site 40 ft. downgradient but were near background concentrations (23).

Using undisturbed soil columns, septic tank effluent (STE), constructed wetland effluent (CWE) and recirculating sand filter effluent (RSFE) results from soil depths of 15 cm (0.5 ft.), 30 cm (1 ft.) and 45 cm (1.5 ft.) were compared (8). Using CWE and RSFE, bacteria were detected at 15 cm but were not detectable at 30-cm and 45-cm soil depths. Bacteria were not detected at the 45-cm depth receiving STE. Additional treatment of STE may allow for reduced depths of unsaturated zone. Otherwise using STE without additional treatment, a 45-cm depth was necessary to virtually completely remove bacteria in this type of soil (fine loamy) (8).

With an unsaturated zone ranging from 1-2 feet below an 8-year old system in sandy soils, normal septic tank contaminants (but with no data on pathogens) were at or below background levels within 20-40 feet of the system (14). The authors concluded that P was significantly attenuated by soils and that substantial N removal was most likely by denitrification in the saturated zone downgradient of the system (14).

A study on the effect of tile drainage on effluent disposal in wet soils determined that tile drains were effective in producing groundwater drawdown without detrimental impacts at the drainage outlet (25). One site, with a vertical offset of 23 cm (9 in.) to SHWT and a 3-m (9 ft) horizontal setback between the tile drain and the disposal lines, did not result in unacceptable quality for drainage water based on Oregon State guidelines (with respect to nitrates and fecal coliform bacteria) (25).

Two studies in which the vertical offset was 2-3 m (6.5-10 ft.) showed that sorption plays a significant role in the retention and biodegradation in the vadose zone of organic chemicals (such as surfactants used in detergents)(13, 20). Chemicals that are less likely to be sorbed and that have a longer half-life are more likely to migrate further and may potentially affect shallow domestic wells that lie in the path of the effluent plume, even at significant distances downgradient from the source (20).

A study in St. Petersburg used relatively low application rates and low influent virus numbers showed viruses present after 5 feet of filtration (21). This reduces confidence in the ability of the soil environment to reduce virus numbers to zero under marginal conditions, which is especially significant when these groundwaters are used for drinking water supplies without disinfection (21). A 3-m (10-ft.) offset to SHWT in another study showed the presence of poliovirus in nearby wells although no fecal coliform bacteria were present (1). This emphasizes the shortcomings of using fecal coliform as an indicator of all enteric pathogens. The absence of fecal coliform bacteria in groundwater does not mean that the groundwater is free of pathogens (1).

The movement of effluent, whether horizontal or vertical, is very dependent upon the water table gradient and the presence or absence of restrictive horizons (5, 6, 22). Vertical movement of contaminants into deeper groundwater is possible when horizontal hydraulic gradients are small and there are no restrictions to vertical movement. Bacterial movement downward to 10 feet was evident 20-40 days after water levels in shallow wells peaked, suggesting mass flow as effluent moved downward with the receding water table (22).

A comprehensive study was made of a conventional system situated on a surficial sand aquifer in southern Ontario (4). The vertical separation was 2-2.5 m (6.5-8 ft.) to the groundwater. The plume of contaminated groundwater at this site was long and narrow and extended at least 130 m (426 ft.) from the tile field. Nitrate levels exceeded drinking water standards. Little dilution (<twofold) and insignificant adsorption and transformations of N occurred. The lack of dilution from dispersion is significant because regulatory agencies generally assume that dilution over relatively short travel distances (20-40 m or 65-131 ft.) will adequately attenuate many contaminants such as nitrate. The subsurface fate of many of the most relevant contaminants in septic systems can be profoundly influenced by site-specific factors. For example, changes in depth to water table or effluent loading rate could result in different transport and fate scenarios (4). For individual sites, the crucial question is how much offset is needed to effectively reduce pathogens (12).

Relative to individual site conditions, a rating system was developed as part of a pilot project in Florida in which soil potential ratings for onsite systems were used, as opposed to traditional soil limitation tables (10). The ratings emphasized feasibility of use and were designed to meet local needs through participation of local technical specialists. Soils that had limitations listed as severe varied in their potential ratings from low to very high based on the corrective treatments deemed necessary to overcome the limitations. An equation was used to determine the soil-potential index (SPI), which included the index of performance, the index of cost of corrective measures, and the index of costs resulting from continuing limitations. The authors concluded that new costs and corrective measures must be developed for each local area; data on soil performance must be collected locally and could differ for the same soils in different areas. A worksheet for preparing corrective measures for the Leon County pilot site listed soil water table conditions of 3-6 ft. and less as having the continuing limitation of possible groundwater contamination (10).

Researchers studied three seasonally used onsite systems in coastal Rhode Island (17). The systems were installed in poorly sorted gravelly sandy fill material; native beach sediments under fill consisted of well sorted medium sands. Clogging mats did not form, resulting in uneven distribution and rapid channelized flow from trenches. With greater than 1.5 m (5 ft.)of vadose zone, bacteria were found at 2 and 6 m (6-20 ft.) away from systems. At the 6-m distance, nitrate-nitrogen was found at levels 3-4 times greater than drinking water standards. The authors concluded that more even distribution, such as low pressure pipe (LPP), and an adequate offset to water table would improve system performance and treatment of effluent (17).

A study in Tennessee compared the performance of two pressure distribution systems built in shallow soils with depths of 45-60 cm (18-24 in.) (16). The below-grade system consisted of distribution pipe at the original ground surface with 6 inches of gravel going into the natural soil and 12 inches of soil covering the lines; trenches were 6 inches wide and spaced at 5-foot intervals. The at-grade system consisted of gravel and pressure distribution line placed at the natural soil surface with 12 inches of cover; beds were 2.5 feet wide and on 5-foot centers. Water samples were collected from large-pore samplers and small-pore samplers located along the trenches at the soil/bedrock interface. Results showed that wastewater renovation was better below the at-grade system due to preferential movement of water through the small pores as opposed to the large pores (tillage was done before system installation to reduce large pore contact). The exception to this was nitrogen which underwent more denitrification in the small pores under the below-grade system. The authors suggest that a somewhat narrower bed under the at-grade system would result in a higher loading rate and thus a higher moisture level under the bed which would be more favorable to denitrification. The authors concluded that 45 cm (18 in.) of soil depth has considerable potential for cleaning wastewater; however, it is unlikely that nitrogen and fecal bacteria can be totally removed within that depth (16).

Bicki and Brown (3) discuss the importance of having an adequately thick vadose zone, the influence of artificial drainage, and the effects human activities can have on artificially raising the water table. According to the literature they reviewed, a vertical separation of 24 inches between the trench bottom and the SHWT is suggested as a minimum soil depth for proper treatment of effluent and protection of groundwater. This depth may not always be adequate to prevent groundwater contamination by bacteria and viruses. They also suggest that the permeability of the soil affects the amount of treatment in the vadose zone (a more highly permeable soil may require more depth for adequate treatment). In addition, effluent discharge to the groundwater may create a mounding effect, thus artificially raising the SHWT and decreasing the vadose zone depth. The SHWT may also be artificially raised by the presence of impervious surfaces (buildings, driveways, sidewalks, etc.) which increases the infiltration of precipitation onto a smaller land area. The use of stormwater detention/retention devices may also artificially raise water tables in a development (3).

Given the variability of the results of the research discussed above, the data from relevant references were plotted to determine if trends in the relationship between vertical offsets to the SHWT and the lateral transport of the contaminants of concern could be established (references listed on the figures are found in the following chapter). This did prove to be an effective method of evaluating the diverse data. Figure 2 shows the elevated concentrations of fecal coliform counts from studies where the offset to the SHWT was minimal resulting in little unsaturated soil available for treatment. Figures 3 and 4 show a similar pattern for nitrate and phosphorus: elevated levels near the drainfields when anaerobic conditions exist due to a minimal unsaturated treatment zone. In contrast, Figure 5 shows far less fecal coliform bacteria (to below 200 MPN/100ml) in systems with a greater than 1 foot aerobic unsaturated treatment zone (compare to Figure 2 and note the log scale). The same pattern of significant reduction can again be seen for phosphorus in Figure 6 (compare with Figure 4). Because nitrate is produced in the unsaturated zone, no improvement (reduction) is expected with an increased offset (Figures 3 and 6). Therefore, it can be concluded that the presence of an unsaturated treatment zone of one foot or more allows for substantially greater treatment of the contaminants of concern than when saturated or near-saturated conditions exist.

Recommendation:

It is difficult to recommend a single "one-size-fits-all" optimal minimum offset distance between trench bottom and seasonal high water table for every site throughout the state. As the literature suggests, what may provide "adequate" treatment in one soil type may be inadequate in another soil type. In addition to soil type and depth of vadose zone, other factors that can influence treatment include method of distribution (e.g., pressure or gravity), pretreatment level prior to distribution, loading rate, distance to receptors, hydraulic gradients, cumulative loading from neighboring systems, and proper maintenance of a system. The contaminants of most concern (pathogens, nitrogen as nitrate, and phosphorus) also behave differently under given environmental conditions. Therefore, any prescriptive standard must be based on a conservative scientific approach. Since the field-based onsite research done in South Carolina (11, 15) has not been able to directly measure impacts from a minimal six-inch separation distance (i.e., unseasonably dry weather resulted in much deeper vadose zones), recommendations must be based on findings from other researchers presented in the literature. As noted in the above discussion of available research, the findings were highly variable. Also, as noted above, researchers did not always stress (or even note) the depth of vadose zone in their evaluation of impacts to groundwater. Where this information was available, the data was plotted to determine if trends or patterns would be evident.

The current six-inch offset to SHWT, coupled with a 50-foot setback to receptors, is likely inadequate as a statewide standard (compare fecal coliform results in Figures 2 and 5). If groundwater mounding is occurring then this minimal offset is even further reduced. Therefore, a greater offset is recommended. In order to select a uniform standard offset for the entire state, one would have to be chosen that would provide protection for the most vulnerable areas of the state. Another approach would be to recommend two or more offsets based on soil type within a category or grouping of soil types. Although the data indicated some differences in potential lateral offsets in “clayey” soils vs. “sandy” soils, the differences in the recommended offsets were not felt to be substantial enough to warrant differing standards.

Based on literature reviewed and the trend analysis of the cumulative available literature data on vertical transport from drainfields of the contaminants of concern (especially bacteria), an offset of 1.5 feet (45 cm) to the SHWT is recommended. It is felt that an offset of 1.5 feet to the SHWT will be protective of potential receptors utilizing the current 50 foot lateral setback. As mentioned above, this vertical offset could be modified (i.e., reduced) depending on other factors such as, potentially, increased setbacks to receptors or advanced pretreatment and distribution systems (see next section).

Another factor that appears pertinent yet unanswerable at this time is how comparable the SHWT is determined by the present criteria used by DHEC personnel in the field. A direct comparison of South Carolina's six-inch offset to that of other states does not seem equatable until the methods of determining SHWT is compared. The assertion in South Carolina is that the method employed here is much more conservative and thus may actually result in a greater offset to the actual SHWT than that reported by other states that require a numerically greater offset. This assertion needs field verification and documentation. It should not affect any of the research results used because actual measurement of water levels in monitoring wells is the standard practice.

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C. Issue: The Evaluation of Potential Groundwater Contamination Beyond Current Setbacks Stipulated in R.61-56

Current Approach

Currently, Regulation 61-56 requires lateral setbacks to groundwater/surface water receptors for septic tank drainfields. As septic tank effluent must obtain additional treatment via the soil and during initial groundwater flow, through filtration, adsorption, chemical breakdown, and dilution, the lateral offset to any potential receptor is an important issue. Since wastewater chemistry is diverse and the different constituents can react independently with the subsurface, those constituents most likely to proceed to receptors beyond regulated setbacks were given special attention in the review of the technical literature. Receptors, as used in this narrative, are the receivers of the groundwater by which the effluent is transmitted. Receptors are where human exposure or surficial environmental impacts may occur. A receptor can be a well, surface water, wetlands, or even a ditch.

Forty-five publications were reviewed for this topic. Although some publications were based on test results from studies conducted outside the southeastern United States, the evaluated chemistry, or chemical reactions, appeared valid for our consideration.

Concerns

The primary concern is whether receptors of the groundwater pathway directly downgradient of septic tank drainfields could potentially have water quality made unsuitable. The reviewed literature indicates that the principal contaminants of concern, with regard to their possible persistence or impact, and whose final renovation sometimes extends over significant distances, are: pathogens (bacteria and viruses), nitrate, and phosphorus.

Pathogens can severely impact drinking water sources and other receptors. Groundwater discharging to surface water can impact the surface water quality itself and certain types of edible shellfish in coastal areas. The receptor can also be potable water wells located near septic tank drainfields.

Nitrate is of concern because concentrations in drinking water exceeding 10 mg/l as N (mg/l-N) have been associated with methemoglobinemia in infants (nitrate has a 10 mg/l-N drinking water limit: Maximum Contaminant Level, or MCL)(21).

Critical phosphorus receptors are usually surface waters. No serious adverse human health effects of phosphorus are documented at the levels found in septic tank effluent. Surface water eutrophication (algal blooms) are commonly associated with increased levels of phosphorus.

Pesticides, herbicides, and volatile organic compounds (such as degreasers) are occasionally introduced into septic-tank systems, with potentially adverse impacts to groundwater if concentrated. Some research is available on such impacts, but effective management for these constituents is in avoiding the introduction, not in septic system design.

Available Technical Information

Pesticides/Herbicides/Volatile Organic Compounds (VOCs)

Several test sites in a mid-western state were used to evaluate the potential impact of pesticides and herbicides introduced into septic tanks at levels comparable to the washing of clothing or the bathing of persons exposed to these compounds from routine usage (7). Results revealed the absence of any pesticides or herbicides in groundwater after the normal establishment of a biomat beneath the adsorption trenches.

Concentrations of VOCs in the subsurface after discharge to a septic tank drainfield have been studied. The origins of the VOCs were household cleansers and degreasers or hazardous wastes from small/light industries which use municipal drainfields (17, 20, 30, 31). The major conclusion was that household concentrations of VOC's do not pose a significant threat to groundwater quality. Drainfields receiving wastewater with high concentrations of oils, solvents or greases do represent a potential problem for groundwater quality and existing or potential receptors. (30).

Nitrate

Ammonia is converted into nitrate in the zone of aeration below the drainfield, and dissolved nitrate then migrates downgradient from the drainfield area. Nitrate is readily transported but under proper conditions is subject to bacterial breakdown (denitrification) producing harmless nitrogen gas. Denitrification often does not occur significantly, however. A degradable carbon source and low dissolved oxygen concentration facilitate the denitrification and one or the other may not occur (24, 28). Groundwater temperatures in South Carolina are generally suitable for denitrification (21). Denitrification seems to be halted when dissolved organic carbon is in low concentrations, thus preventing a food source for the denitrifying bacteria to utilize (28, 41). Some nitrate dilution always occurs in transport away from the drainfield, but is highly variable depending on site factors.

Studies in Florida soils indicated a wide variety of results (2, 22, 26, 39). In a study of a 50 year old septic system reduction to the 10 mg/l nitrate level was not achieved within 25 meters (82 feet) of the source area (26). One septic system located 20 meters (65 feet) from a canal was studied and it was determined that background conditions were met within 15 meters (50 feet) of the source area (2). A seven year old system was evaluated and background conditions were realized within 12 meters (40 feet) of the source area (22). Investigators attributed the reduction of nitrate to dilution and/or denitrification. They also acknowledged that the denitrification processes, if present, may not continue indefinitely and nearby surface waters might become impacted at some point. The study of a 10 year old system showed that nitrate was at background conditions within 50 feet of the source area in both sand and limestone sediments (39).

Several North Carolina studies were completed in coastal plain soils (9, 12, 13). In one study nitrate under 10 mg/l-N appeared inside three meters (10 feet) of the drainfield (9). Another study revealed seasonal fluctuations of nitrate up to 15 mg/l-N. A third study found concentrations over the 10 mg/l-N level (12, 13). None of these studies determined the groundwater quality beyond a 3 meter distance; however, all of the studies interpreted that denitrification was a prominent factor in the decrease of nitrate concentrations at these distances. The ages of these systems were not stipulated.

Two studies were conducted in coastal plain soils of Virginia (27,36). A study by Reneau (1977) correlated the changes in groundwater electrical conductivity (Eh, relates generally to oxygen availability) to denitrification over a period of four years. At a distance of 3 to 4 meters (10 to 13 feet) the effects of denitrification in groundwater were evident. However, there was no significant appearance of nitrate above the 10 mg/l level at 0.15 meters from the drainfield. Nitrate levels were highest at 3 meters from the drainfield but were still below the MCL. Another Virginia study detected 112 mg/l-N nitrate at the source area and 4.6 mg/l-N at 8.4 meters (27.5 feet) downgradient, which was the furthest extent of the study.

Other researchers cite varying conditions and results. An Arkansas study indicated that the mean value of nitrate was less than 6 mg/l-N throughout the test at a distance of only 100 cm (39.3 inches) from the trench (42). A regional study where septic systems are used as the means of wastewater disposal found that the levels of nitrate increased during the winter months, had a cumulative effect over time and the general trend of groundwater quality was deteriorating (14). In Wisconsin, nitrate was reduced to near MCL concentrations within 6.4 meters (21 feet) of the adsorption trenches (10). A study of seasonally used septic tanks of Rhode Island found that concentrations of nitrate in groundwater increased from background levels of 1.0 mg/l-N, or less, to over 50 mg/l-N at a distance of 20 feet from the drainfield trenches (25). Canadian studies reflect that possible low concentrations of available carbon may be the reason behind nitrate levels above 10 mg/l-N at a distance of 25 meters (83 feet) from their source, the drainfield or experimental areas (5, 29, 38, 41). The distance which nitrate continued to exceed 10 mg/l-N in one study was 130 meters (426 feet) downgradient from the source area (29).

Data from the various studies evaluated were plotted to determine if trends or patterns could be established. Figure 8 shows the decline in nitrate concentration with distance from the drainfield (under both aerobic and anaerobic conditions). The data show nitrate concentration reduced to below maximum contaminant levels (also near to and/or below detection limits in many cases) within 50 feet of the drainfield under most conditions.

Phosphorus

Phosphorus (mainly phosphate) is another of the more prevalent compounds found in septic tank effluent. In North America, surface waters receiving groundwater containing phosphorus from septic-tank systems have experienced algal blooms due to input of this nutrient. Aquatic plants including algae will increase in growth until available phosphate or nitrate is depleted (45). Because phosphorus is usually the limiting factor, relatively small additions of phosphorus can promote optimum conditions for algal blooms. Surface water concentrations in excess of 0.01 mg/l of inorganic phosphorus are optimal for algal growth (44).

Research pertaining to septic tank effluent disposal has shown that phosphorus concentration does attenuate in the subsurface. For instance, in Florida a fifty (50) year old drainfield was evaluated and groundwater quality from monitoring wells revealed phosphorus was attenuated to 1.0 mg/l in 15 meters (50 feet) (26). Typical concentrations of P in effluent entering drainfields, prior to soil treatment, is on the order of 18 to 29 mg/l. The soils in this study were medium to high permeability. A study of a single family dwelling inhabited by five residents showed groundwater concentrations of total phosphorus at 2.26 mg/l within the drainfield and concentrations of 0.02 mg/l at 15 meters (50 feet) downgradient of the drainfield (2). Two nearby sites in different lithologies (sand and limestone) were evaluated and dissolved orthophosphate concentrations were 0.50 mg/l and 0.26 mg/l at 50 feet down gradient in the sand and limestone, respectively (39).

Evaluations of phosphorus with regard to septic effluent were also made in North Carolina (9, 12, 13). Septic tank drainfields in Craven, Hyde and New Hanover counties reflect a minimal phosphorus impact on the groundwater quality. A study on a coastal barrier island soil, a fine sand, revealed low phosphorus adsorption and increased mobility under wet conditions (12). Also noted in this study was the remobilization of phosphorus when a flushing event took place (i.e., increased loading of the tile field or heavy precipitation). The drainfields with the largest separation to the water table had the lowest mean concentrations of soluble phosphorus (0.1 to 2.0 mg/l) in groundwater. The lateral migration of phosphorus was not evaluated. Another North Carolina study revealed minimal migration of phosphorus (9). Although the study does not detail the distance of migration, most sites indicated groundwater concentrations below the quantitative limit of the tests (<0.05 mg/l) at sampling locations not far from the drainfield areas. The absence of phosphorus in the groundwater was attributed to the presence of iron and aluminum in the soils which increased the soil adsorption of phosphorus.

Groundwater quality monitoring in a study conducted in Virginia did not indicate any concentrations of phosphorus above the quantitative detection limit of 0.01 mg/l, though the effluent contained 10.7 mg/l upon entering the drainfield. Monitoring wells were located at the drainfield and at 2.8 and 8.4 meters downgradient (9 and 25.5 feet, respectively) (36).

An Arkansas study revealed that septic effluent containing mean dissolved orthophosphate concentrations of 15.7 mg/l was reduced by soil fixation to a concentration of 0.86 mg/l at a distance of 100 cm (39 inches) from the drainfield trench (42). The soil was a Calloway silt loam that is poorly drained.

In Rhode Island, average phosphorus concentrations of septic tank effluent of 3 systems was 13 mg/l. At 6 meters (20 feet) from the drainfield, groundwater concentrations of total phosphorus had diminished to 0.89 or 0.01 mg/l (25).

Canadian studies have determined that phosphorus is present only as a localized characteristic in groundwater beneath septic system drainfields, and is presumably adsorbed in the soil above (29,41). A Connecticut study measured vadose zone fixation of soluble inorganic phosphorus in soil solution within 120 cm (4 feet) vertically (32).

A plot of available data in Figure 9 shows substantially reduced phosphorus concentrations within a distance of 25 to 50 feet from the drainfield.

Pathogens

Fecal coliform bacteria and infectious viruses are of high concern in being transported via the groundwater pathway to receptors. One paper summarizes many publications in which the pathogenic contamination associated with septic tank effluent showed a wide variety of outcomes (11). The variations in pathogenic migration were correlated to seasonal fluctuations of the water table, the extent and distance to which the effluent received aerobic treatment before encountering the water table, types of soil the organisms passed through, and the types of bacteria and viruses themselves. Some pathogens had traveled laterally 50 feet just one hour after being introduced into the subsurface in coarse soils. Some pathogens are adsorbed on to the soil particles while others are transported though the soil matrix where reductions occur via natural die off (34).

On a barrier island in North Carolina, soils were analyzed for fecal coliform below two drainfields (12). The drainfield with the largest zone of aeration had nearly complete removal of bacteria. Another study initiated research by introducing viruses into a septic tank system (9). The organisms persisted up to 59 days in one case and were also detected at the furthermost groundwater monitoring located 35 meters (115 feet) downgradient.

A Virginia study showed that systems with a good zone of aeration typically restrained bacterial migration to within 1.5 meters (5 feet) of the drainfield trenches. Another study determined that bacterial removal was highly variable at 6 meters (20 feet) (36). Studies in areas with high seasonal fluctuating water tables showed some locations where fecal coliform movement was up to 28 meters (92 feet) from the source area (35).

Viral transport has been studied less than other contaminants and is not as well understood. Temperature is one of the apparent keys to viral persistence. A lower temperature is conducive to the survival of viruses in the subsurface (43). Most groundwater is fairly cool. Soil type is also a factor in viral persistence. Some viruses are adsorbed onto soil particles and thus are retarded in their migration (16, 32). This seems to occur most often in soils containing clays. Excessively drained (sandy) soils seem to only temporarily retain the organisms until flushed out of the zone of aeration by increased drainfield loading with wastewater or by precipitation, which reactivates the migration of some organisms (33).

Fecal coliform concentrations with distance from the drainfield were plotted in Figure 10. The reductions with distance seen with nitrate and phosphorus were also apparent for bacteria but the distances required for a reduction to below an acceptable level (200 MPN/100ml for surface water, 14 MPN/100 ml for shellfish harvesting, and zero for drinking water) were significantly greater. The available data suggest, by extrapolation, that concentrations would generally be reduced to below even the shellfish standard within about 125 feet from the drainfield (even under saturated conditions).

A related issue to lateral offsets is the potential cumulative impacts of multiple OWDS (such as in a subdivision). Cumulative impacts are not specifically considered by Department personnel as each lot in a subdivision is individually evaluated. Similarly, the existing water quality (i.e., are there data showing impacts from nitrogen, phosphorous) of a nearby surface water body are not considered in the permitting process as lateral offsets of 50 feet are specified in the current regulation (R.61-56). No discussion or recommendations concerning minimum lot sizes are provided as inherent in the recommendations in this report for vertical and horizontal offsets (and operation and maintenance), are adequate distances that will mitigate cumulative impacts and/or impacts to sensitive surface waters (i.e., where concerns about eutrophication or bacteria exist).

Recommendations

Denitrification is the main process by which nitrate actually can be eliminated as a contaminant under subsurface conditions. Site conditions vary drastically across South Carolina and many areas are not conducive to denitrification. This leaves dilution as a primary process in ameliorating nitrate. Most literature reviewed indicates that nitrate concentrations will be reduced to acceptable levels within 50 feet of the drainfield.

Phosphorus, under a majority of situations, will attenuate via soil adsorption. Most of the literature reviewed indicates this occurs within 50 feet. The attenuation of this parameter is dependent upon soil conditions. Adsorption onto very sandy soils has been found to be somewhat weak and temporary. Flushing can occur which may disperse the phosphorus farther from the drainfield area. As with nitrate, in some reviewed literature, it is suggested that as the attenuative capacity of the soil is reached phosphorus migration will continue. It should be noted that most of the studies of phosphorus did not evaluate the concentrations down to 0.01 mg/l which is the level associated with surface water eutrophication.

Pathogens are the least understood contaminant and therefore may be of the greatest concern. Migration paths of a hundred feet or more were noted in the literature. This migration appeared to be more prevalent under wet season conditions, i.e., high seasonal water tables and lower temperatures. Viral transport particularly is not well understood. By using fecal coliform bacteria as an indicator of pathogens, and by plotting the data obtained in references, a pattern of reduction of fecal coliform in the groundwater can be established. Because pathogens were not reduced with distance as significantly as nitrogen and phosphorus, fecal coliform counts can be used as the most conservative contaminant of concern (i.e., horizontal setbacks established for fecal coliform reduction will be very protective of nitrogen and phosphorus impacts).

The treatment and disposal of onsite wastewater occurs in both the vertical dimension and in the horizontal dimension (in both soils and groundwater). Therefore, establishment of protective lateral offsets to potential receptors cannot be discussed without consideration of the vertical offset to the SHWT. Therefore, two options are provided for consideration:

- Option 1 is based on the recommended 1.5 foot vertical offset to the SHWT. If the current six inch vertical offset to the SHWT is increased to eighteen inches and is adopted as the new statewide standard, the current lateral offset of 50 feet appears to be much more protective of all receptors under most hydrogeologic conditions expected to be present in South Carolina.

- Option 2 is based on the observed relationship between fecal coliform reductions and vertical offset to the SHWT. Permitting would be based on a "sliding" scale that incorporates the available treatment in both the vertical (unsaturated zone) and horizontal (groundwater) dimensions. Vertical offsets to the SHWT less than eighteen inches but greater than six inches could be allowed given sufficient lateral offsets to potential receptors.

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D. Issue: MAINTENANCE, REPAIR, AND UPGRADE OF OWDS

Current Approach

Maintenance of onsite waste disposal systems (OWDS) includes maintaining cover, mowing grass and routine pumping of the septic tank in a conventional or modified conventional OWDS. A repair is usually the addition or replacement of a drain line on a malfunctioning OWDS. An upgrade is the improvement of a malfunctioning OWDS so that it will meet or exceed current standards for a new OWDS as required by Regulation 61-56.

Regulation 61-56, Individual Waste Disposal Systems, does not address routine maintenance of OWDS. The regulation does not require that failing OWDS be upgraded to current standards. Regulation 61-56 states that the Health Authority may require a permit for the repair, extension, or alteration of an individual sewage treatment and disposal system(19). The regulation also states that in the case of repairs to existing individual sewage treatment and sewage disposal systems, the Health Authority may authorize the best possible method of repair, regardless of site conditions.(19)

The permitting and inspecting of repairs to malfunctioning OWDS and upgrades to existing OWDS are not currently possible with the current funding level and available manpower in the Environmental Health Division; nor has the necessary level of financial support required to accomplish this task ever existed in the state. Upgrading malfunctioning OWDS to meet current standards has not been politically acceptable due to the excessive costs of alternative technology and the routine maintenance required by these alternative systems.

CONCERNS:

Routine maintenance is recommended by many authorities and researchers who have studied the causes for OWDS to malfunction. How do we define routine maintenance? How can it be required? How do we ensure that it is performed?

Repairs to malfunctioning OWDS must be permitted and inspected to ensure that the repair installation meets the requirements of the permit and to ensure that the repair does not violate the regulation.(1)

When repairing a malfunctioning OWDS, the system should be upgraded so that it meets current standards as defined in the regulation.

The issues of routine maintenance, permitting repairs, and upgrading malfunctioning OWDS have a direct impact on water quality and quality of the environment. If these issues are not adequately addressed, water quality will degrade and there will be a detrimental effect on the environment and potentially on human health (10,11,12).

Discussion of Available Technical Information:

MAINTENANCE

Wastewater Disposal Systems (OWDS) have traditionally been the responsibility of the homeowner. System failures can occur due to homeowner misuse and improper maintenance. Other reasons for OWDS failures include improper siting, inaccurate assessment of soil characteristics, improper loading rate, and improper installation. An excess accumulation of solids results in insufficient capacity for clarification of the sewage in the tank which results in solids entering directly into the drainfield and ultimately causing clogging of the drainfield and the soil pore spaces. The end result is surfacing of the sewage effluent (malfunctioning). Routinely pumping the septic tank will alleviate this problem.

The maintenance of conventional and modified conventional OWDS have traditionally been the responsibility of the home owner and the homeowner usually has the attitude, "If it's not broken . . . don't fix it." The reasons for failures of OWDS have been well documented; improper siting, inaccurate assessment of soil characteristics, improper loading rate, and improper installation are not controlled by the homeowner (16,20). The homeowner has responsibility to maintain the vegetation covering the OWDS, to restrict vehicular traffic from the area occupied by the OWDS, to not overload the OWDS and to be aware of excess accumulation of solids in the septic tank. An excess accumulation of solids results in insufficient area for clarification of the sewage in the tank which results in solids entering directly into the drainfield and ultimately causing clogging of the drainfield and the soil pore spaces. The end result is surfacing of the sewage effluent (malfunctioning). Routinely pumping the septic tank will alleviate this problem (17,15). The recommended frequency of pumping varies from two years to ten years (12,13). Manel developed a frequency table that makes a recommendation of pumping frequency based on the relationship between the number of occupants in the house and the size of the septic tank. For example, a family of four and a 1000 gallon septic tank would require pumping every 2.6 years (16).

Alternative/innovative OWDS, i.e., systems with electro/mechanical devices, pumps and pressure distribution systems will require more frequent inspections and maintenance to ensure proper operation. Some references show how required inspections and maintenance can be accomplished by a governmental entity, i.e., a sewer district, a municipality, or a county, etc. (21,2,24,23).

RECOMMENDATIONS:

It is recommended that an annual inspection be performed of the OWDS, at which time the depth of sludge is measured, and based upon these results determine if pumping is necessary. Access risers on the septic tank will facilitate inspections. In the absence of an annual inspection, it is recommended that the septic tank be pumped at least every five years. Alternative/innovative OWDS, i.e., systems with electro/mechanical devices, pumps and pressure distribution systems will require more frequent inspections and maintenance to ensure proper operation. There are many options for establishing an inspection and maintenance program, some of which can be accomplished by a governmental entity, e.g., a sewer district, a municipality, or a county, etc.

Also recommended is increased public awareness and education regarding routine inspections and maintenance of OWDS. The Department could produce media spots for television and radio and develop other educational materials.

Malfunctioning OWDS must be repaired so as to eliminate not only a discharge to the surface of the ground, but also to prevent contamination of the groundwater and the environment. This can only be accomplished through an organized system of evaluating malfunctioning OWDS, issuing a permit for the repair and ensuring that the repair is properly made by performing a final inspection of the repair prior to closing or covering the OWDS. Determining the feasibility of an inspection and certification of a properly functioning systems at the "point of sale" is also recommended. Inspections for termites and heating and air conditioning systems are currently conducted when private real-estate is sold; a similar process could be developed for OWDS.

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E. Issue: Operational Permits for Onsite Wastewater Disposal Systems

Current Approach

Currently in South Carolina, OWDS permits are construction and use approval permits.

Concerns

With the advent of innovative technologies, which include more complex mechanical devices, there may be an inherent need for routine evaluation, operation and maintenance of these wastewater systems. This could be accomplished through an operational permitting process to ensure that the more technologically advanced treatment systems achieve established performance standards.

Discussion of Available Technical Information

An operational permit is issued for a specific period of time and has quality assurance requirements built in which necessitates proper management of the system based upon certain design parameters and expected performance standards. Basic to this type of program is routine monitoring. Often, this is accomplished by oversight performed by a certified wastewater systems operator. It has been documented that the average homeowner is not knowledgeable enough in the technical operation of advanced treatment systems to provide the critical operation and maintenance (O&M) necessary to ensure the long term satisfactory operation of the waste disposal system. Another consideration of an operational permit program is the perpetual cost associated with the implementation of such a program. In order to operate an effective program sufficient resources must be dedicated for surveillance, routine monitoring, training, system repair, system replacement, and program oversight.

Recommendation

At present, there seems to be little information available from other states on operational permit programs. The cost involved, necessary manpower, and other considerations could be partly the reason why many states have not initiated a mandatory operational permit program. Operational permits, at least at the state level, do not appear to be feasible for use in South Carolina at this time.

F. Issue: Evaluation of Onsite Wastewater Alternative Technologies and Advance Treatment Methodologies

Current Approach

Regulation 61-56 currently defines the use of conventional onsite wastewater systems and allows for the development of standards for alternative wastewater systems. Through a process of innovative design and field testing of systems over a period of time, many standards have been developed by the Bureau of Environmental Health which have been the guiding criteria for use of alternative designed systems in South Carolina.

Standards which have been developed must adhere to the minimum site and soil restrictions governing conventional system criteria. Standards may have more restrictive site and soil criteria, i.e., set back restrictions from environmentally sensitive waters, offset to seasonal high water tables, etc., but cannot be less restrictive. One consideration in the development of alternative standards has been to design systems which would not require extensive maintenance.

In South Carolina, onsite wastewater permits serve as both construction and use approval permits, though not operational permits. Operational permits would require certified wastewater operators to ensure proper maintenance and operation of those more complex and technical maintenance intensive systems. Based upon the socioeconomic factors, financial concerns as well as maintenance and operational concerns of advanced treatment technologies, the trend has been to focus on design modification of predominately gravity based lower maintenance, thus more consistently reliable, systems.

In addition to the work South Carolina has been involved with, extensive considerations have been given to alternative wastewater system designs both on a regional and national level. South Carolina DHEC has adopted a "demonstration protocol" procedure which allows for new, innovative alternative systems and alternative wastewater products to be used and tested in our state.

Concerns

As stated in the introduction, when consideration is given to using alternative wastewater system designs and/or products, one must certainly consider the amount of maintenance which will be required to insure adequate wastewater treatment and to insure the system will continue to function as designed. Also, who will provide the maintenance? Other considerations would include expected or unknown success/failure rates of various system types, system life expectancy, start up costs, and operational and maintenance costs. Not all alternative systems give complete treatment. Some seem better at removing or treating various components of wastewater than others.

Available Technical Information

The following is a brief outline and discussion of the more common types of alternative wastewater systems. Each will be addressed individually as to their strengths and/or weaknesses.

Mounds

Mound systems are generally used in an attempt to overcome seasonal high water table conditions. They consist of a septic tank, an effluent pump chamber and an elevated sand mound. Mound systems have been around for twenty years plus. While mound systems are designed primarily to elevate the treatment zone above the season groundwater table, their failure rates have been documented to be unacceptably high (13). Surveys in Virginia, Wisconsin and Pennsylvania in 1980, 1985 and 1991 revealed failure rates of 50%, 21% and 24% respectively. The most common reasons of failure were poor distribution patterns, slope, erosion, and lack of maintenance. An additional drawback was the high cost of construction (two to three times more than conventional systems). Another concern is the unpredictability of the effectiveness of mound systems in overcoming water table limitations. In some cases, capillary action or "wicking" will actually cause the water table to rise near to the mound base, or into the mound itself.

Low Pressure Distribution

Low pressure pipe (LPP) systems are designed to distribute wastewater effluent by using a mechanical pump to transport the effluent through small diameter pipes containing small holes for the purpose of evenly distributing the effluent loading throughout the absorption field. Theoretically this helps to prevent or minimize clogging mats from forming in the absorption field (13,14). Maintenance seems to be the biggest liability. Pump failures, clogging of distribution pipes and groundwater infiltration are just a few of the reasons cited for system failures.

Aerobic Treatment Units

ATUs utilize aeration via forced air or mechanical mixing to improve the treatment capabilities in the primary chamber. ATUs are generally used in place of a septic tank in the initial treatment phase. High numbers of aerobic microbes convert organic matter into less damaging and more common chemical compounds. However, studies have shown that ATUs have a high range of treatment variability. Proper maintenance is key. Variability in treatment quality can be related to maintenance problems, homeowner neglect and wastewater flow surges (14). Studies have shown that effluent from ATUs was not of high enough quality to be surface applied and needed additional treatment.

Sand Filters

Sand filters are generally used in the secondary or final phase of treatment. Sand filters are installed in line after the septic tank. The septic tank is used to reduce the total suspended solids prior to distribution of the effluent into the sand filter. Sand filters can be below or above ground and are beds of sand filter media generally 2 to 3 feet (61 to 91 cm) deep that are underlain by gravel and a collection system. Recirculating sand filters are useful in removal of nitrogen as well. Treatment obtained from a single pass recirculating sand filter is equivalent to tertiary treatment from a wastewater treatment plant (11). Recirculating sand filter with UV disinfection produces an effluent of such high quality that North Carolina rules allow for surface irrigation around homes. Pathogen reduction in a recirculating sand filter is roughly equivalent to treatment received from a conventional septic tank system underlain by 6-12 inches of suitable fine textured soil (5).

A study conducted at the University of California compared 6.5 to 9.79 feet (2-3 meter) sand filters with shallow 2 feet (0.6 meter) sand filters. When the dosing rates were above twelve (12) times per day, excellent results were achieved. Sand filters have been used for 100+ years all around the county. Keeping the sand filter water tight is a critical issue (1). Sand filters do require periodic maintenance. Sand filters have been successfully used by many homes, schools, businesses and communities in the USA as a low cost, energy efficient alternative to centralized wastewater treatment. Because they provide high quality treatment, sand filters are a viable option for environmentally sensitive areas especially where conventional septic tank/ soil absorption systems have failed (5).

Peat Filters

Peat filters are filter systems used to provide for secondary treatment of STE and are located after a typical septic tank. Many different species or types of peat (Reed sledge, Sphagnum, etc.) have been studied. The sphagnum peat, generally found in areas of the NE United States and in eastern Canada, seem to have the more desirable qualities for STE treatment (12). Sphagnum peats have been found to be resistant to decay even in aerobic conditions. It has been suggested that STE not only provides the necessary nutrients but is also a more readily available source of organic carbon (C), thereby minimizing the need for the use of peat as a carbon source. Studies have shown peat filter systems giving excellent treatment results after eight years of use.

Research has demonstrated that loading rates for peat should probably not exceed 4.1 cm/d for typical strength STE (12). Many design parameters have been studied both in the laboratory and in the field with results indicating that a minimum of 30cm of lightly compacted peat (0.10 - 0.12 mg/m) below the distribution pipes is recommended. Filter beds as small as 4.8m by 6.1m using 30cm of peat have been demonstrated to provide adequate secondary treatment for failing systems for a typical single family home.

Peat filter beds provide excellent organic and fecal coliform removal without additional disinfection. Transformation of N components through nitrification and to a lesser degree denitrification, is adequate with effluent quality below the 10mg/L recommended level (12). Phosphorous, on the other hand, is much more troublesome and difficult to achieve good reduction. Even though P seems to be more difficult to reduce in the bed, it should be noted that further attenuation occurs as the effluent moves through the natural soil. It is interesting to note cold weather seemingly has little or no adverse effects on the satisfactory operation of sphagnum peat systems. Also interesting is the fact that research has shown that the method of distribution (gravity, dosing or pressure) seems to have little impact on the degree of treatment obtained (12).

Recommendations

While various alternative and experimental designs for OWDS exist, no one particular design offers a complete panacea for all treatment criteria and pollution concerns. For example, Aerobic Treatment Units (ATUs) provide for excellent treatment of bacteria due to increased aerobic activity in the tank yet have little or no effect on phosphorus (P) and nitrogen (N). Of the systems examined in the literature, sand filters and sphagnum peat filters show the most promise. Not only do they give excellent treatment results, with the exception of some contaminants (primarily P), but require less frequent and less labor intensive maintenance. The selection of an alternative technology as a method of onsite waste disposal and treatment must be carefully made based on a decision relative to the specific site and sizing criteria, soil types, topography, proximity to environmentally sensitive areas and others.

Maintenance of alternative systems plays a significant role in the ultimate performance of these type systems. The more complex and technologically advanced or innovative a system is, the more that maintenance is a critical factor in the long term success or failure of the system. Maintenance and Operational permits or contracts could be established with local governmental entities (such as water and sewer utility companies) which could guarantee reliable and dependable maintenance on a routine frequency. Another recommendation is to adopt and include in the state's onsite wastewater regulation, provisions which would allow the use of alternative technology systems and at the same time require acceptance of maintenance by a regulated utility.

A key to general acceptance of new and innovative technologies is to find a mechanism whereby both the knowledge and understanding of how various systems function can be gained, as well as an evaluation of their individual strengths and weaknesses. One means of accomplishing this is through the creation or establishment of state, regional or local wastewater training centers. Wastewater training centers are typically designed to display current alternative technologies in the wastewater industry. Centers can be designed for display and training for system technologies or can also include provisions for research and data collection to compare treatment potentials and performance standards with desired results. A cooperative effort involving the research, educational, regulatory, and private sectors and adequate funding are critical to the success of such a program (NC State University has established a model program).

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G. Issue: Evaluation/Applicability of Performance Standards

Onsite wastewater regulations are typically prescriptive codes; that is, the regulations define or prescribe specific system design requirements (system components, materials, dimensions, installation methods, etc.), and siting requirements (soil conditions, topographical limitations, minimum setback distances to wells and surface water features, etc.). A level of treatment effectiveness is implied, rather than specified. Systems are evaluated based on their compliance with the standards rather than on actual performance. Systems that meet the required design and siting standards are assumed to provide a level of treatment necessary to protect public health and environmental quality, which are the objectives typically stated as the basis for the prescribed standards.

An alternative approach to onsite wastewater regulation currently being discussed focusses on the development and implementation of performance standards, which define wastewater treatment objectives by specifying measurable performance requirements, taking into account the volume and characteristics of the wastewater generated, site and soil conditions, and assimilation limitations of or potential impacts on the specific receiving environment. After appropriate performance requirements have been determined for a particular application, a system design is then developed which is capable of providing the specified level of treatment. System designs typically are developed by engineers or certified design specialists, and should include a schedule of system maintenance requirements, a monitoring protocol for ensuring that the system's actual performance meets the design treatment specifications, provisions for ensuring that maintenance and monitoring activities will be performed as outlined in the proposal, and contingency plans for correcting performance failures. The performance-based approach reflects a philosophy that "each system must be designed to conform to site conditions rather than requiring site conditions to conform to criteria established for system design."(10)

Current Approach

The current onsite wastewater regulatory program in South Carolina, as in most jurisdictions, is based on prescriptive standards. Regulation 61-56, Individual Sewage Disposal Systems (11), which governs the design and placement of onsite systems, defines the minimum requirements and criteria for system design, siting, and construction. The regulation also provides authority for the department to establish standards for alternative systems. Alternative system standards, also prescriptive, have been developed to address specific site and soil limitations which preclude the installation of conventional system designs.

After a proposed site has been evaluated by department staff and approved for installation of an onsite system, the department issues a "Permit to Construct", which states the required design specifications and indicates the location of the specific area approved for system installation. The permit may also include statements explaining additional specific requirements pertaining to the system construction or conditions for approval. Final approval for use of the system is issued after an inspection of the system installation confirms that the system has been constructed in conformance with the specific requirements stated on the permit and with Regulation 61-56.

Concern

Concerns related to specific requirements of Regulation 61-56 and current standards are discussed in depth in other sections of this report. This section lists general concerns related to the limitations of regulatory programs based on prescriptive standards.

1. It is unclear to what degree systems which meet prescriptive standards are effective in providing adequate levels of treatment to meet public health and environmental quality goals in all receiving environments. The treatment capabilities of conventional septic tank/soil absorption system designs have not been clearly defined. Performance standards for these basic systems have not been established. Typically, treatment concerns have been addressed in prescriptive standards through built-in "safety factors", not specifically defined but incorporated into aspects of design standards such as system sizing methods and physical separation or setback requirements from water bodies and wells. Safety factors provide a margin of error to handle variations in the flow or strength of wastewater, the permeability and treatment capability of the soil, and other factors which affect system performance but are difficult to accurately predict. Safety factors help to ensure that systems will have a long service life through a broad range of use conditions and with little maintenance.

2. Prescriptive regulatory approaches may lack provisions for effective ways to incorporate into system design requirements the range of limiting factors characteristic of various receiving environments. Of particular concern are the potential impacts of onsite system use on water quality and aquatic life in nutrient- and/or bacteria-sensitive coastal waters or freshwater lakes.

3. Prescriptive standards may not adequately address potential impacts of high-density onsite system use in areas experiencing rapid increases in population.

4. Because they do not explicitly address actual system performance, prescriptive standards may be perceived to be concerned primarily with wastewater disposal and prevention of surface discharges, rather than ensuring that adequate treatment is provided by specifying that measurable performance requirements be met.

5. Prescriptive regulatory approaches often do not include requirements or provisions for maintenance of onsite systems, and do not require that onsite systems be inspected at regular intervals to monitor their condition and to determine whether they are functioning. In the absence of requirements for maintenance in the regulations, infrastructure development for addressing system maintenance needs receives little attention.

6. Prescriptive regulatory approaches do not promote the use of innovative technologies designed to provide higher levels of treatment than conventional systems, but which do not meet the codified system design options. Prescriptive standards do not include provisions for the use of innovative systems on sites where site or soil conditions are not suitable for conventional systems. With the use of more technologically advanced systems, adequate provisions for operation and maintenance become more critical, but operation and maintenance resources are either absent or severely limited in most jurisdictions. As population densities and property values increase, there may be a greater willingness on the part of prospective homeowners to utilize innovative treatment systems and to pay the increased costs of installation, operation, and maintenance of these systems; however, prescriptive regulatory programs typically do not include provisions for this option.

Discussion of Available Technical Information

The issue of development and adoption of a performance-based approach to onsite wastewater management has been discussed among the onsite community over the past decade. In 1991, in the keynote address to a national meeting of onsite wastewater professionals (8), Richard Otis reviewed the history of the use and the study of onsite systems, discussed the shortcomings of the established regulatory approach, and called for a national effort to define acceptable onsite system performance and to replace prescriptive codes with a performance-based approach to system design and regulation.

The report of a 1993 conference to address possible improvements for onsite wastewater system regulation in shellfish harvesting areas of the Gulf of Mexico (12) included a recommendation that each Gulf state should establish performance standards for onsite wastewater systems where possible, stating that "performance standards can stimulate innovative designs and allow ideas that work to prove their value".

Recommendations to improve onsite practices in Florida, made in 1993 as a result of the Florida Onsite Sewage Disposal System Research Project (9), included a recommendation for the development and implementation of a performance-based program for siting, design, construction, and management of onsite wastewater treatment systems, in conjunction with the continued use of prescriptive design options meeting a minimum standard of performance for sites meeting specified criteria.

A 1994 report (10) discusses five basic elements that onsite wastewater management programs must have in order to ensure that onsite systems provide "satisfactory, low-cost wastewater treatment and disposal in unsewered areas," and which are essential in order for onsite systems to "be regarded as effective and permanent facilities". These elements are listed as follows:

- clear and specific performance standards.

- technical guidelines for site evaluation, design, construction, and operation.
- regular compliance monitoring (perpetual monitoring is necessary to ensure continued performance levels).
- licensing or certification of all service providers (including site evaluators, designers, contractors, operators, and regulators). Training and continuing education needs must be addressed.
- effective enforcement mechanisms (including the assessment of fines and penalties).

In 1996, the National Onsite Wastewater Recycling Association (NOWRA) published a document proposed for use as an outline or framework for specifying a performance standard for a particular application (7,5,6). The document was designed to be flexible so that it could be used for defining specific measurable standards for different receiving environments and applications in any jurisdiction. Rather than proposing specific requirements such as acceptable parameter values, provisions for maintenance, etc., the document lists aspects of performance which should be addressed in specifying a performance standard for a particular application, including treatment evaluation parameters, characteristics of the receiving environment, identification of sampling points, and others.

In 1998, a proposal was made for the adoption of a series of national treatment performance standards for seven levels of treatment (3). The treatment levels addressed include primary treatment (with two categories - filtered and unfiltered), secondary treatment, tertiary treatment, nutrient reduction (with three categories - nitrogen reduction, phosphorus reduction, and nitrogen and phosphorus reduction), bodily contact disinfection, wastewater reuse, and near drinking water. Suggested constituent concentration limits are offered for BOD, TSS, orthophosphate, ammonium-nitrogen, nitrate-nitrogen, total nitrogen, and fecal coliform colony densities. It is proposed that the American Society of Agricultural Engineers (ASAE) 262 Committee take leadership in developing the standards through the establishment of an expert panel to serve as a Standards Writing Subcommittee. The intent of the national performance standards is that jurisdictional regulatory programs would voluntarily adopt the standards for application to performance-based system designs. Advantages of a set of national standards would provide that regulators in each jurisdiction would not have to independently determine appropriate standards of performance for each level of treatment, and that system designers and component manufacturers would be able to address consistent and well-defined treatment goals across jurisdictional boundaries, rather than having to repeatedly satisfy varying ranges of standards required in various jurisdictions.

In March 1998, the state of Florida enacted revised onsite regulations incorporating standards for performance-based treatment systems (14). The regulation defines standards for onsite systems in several categories, including a baseline system standard (addressing both septic tank effluent and percolate concentrations after movement through two feet of unsaturated soil), secondary treatment, advanced secondary treatment, and advanced wastewater treatment. Each system design must be certified by a professional engineer and submitted to the county health department. The regulation specifies time-frames within which the health department must make a permit decision. After permit approval and system construction, an operating permit and system maintenance and monitoring are required for each approved installation.

The state of Wisconsin began developing codes for performance-based standards in 1991 (1,14). Efforts to gain public approval of the revised codes were made in 1995 and in 1997, but were not successful due to citizen opposition to the nitrogen requirements which were judged to be cost-prohibitive, and to opposition from environmental groups who were concerned that the code would result in an elimination of barriers to land use development that exists under the prescriptive code, and would promote urban sprawl. Landowners and developers favor the code revision because it may afford a wide range of system options that would make it possible to develop lots which could not be developed under the prescriptive code. County officials who will be responsible for administering the application of the new code requirements feel that they must be provided additional training before the code can be placed into effect.

Don Alexander, Virginia onsite program director, has said that "whatever we do with wastewater treatment, we're not going to have zero impact - that's not realistic. We need to define what impacts we can live with"(4). A risk-based approach to system siting, design, and management has been recently proposed as a systematic qualitative method for assessing the risks from onsite systems on a watershed basis and considering the value and vulnerability to pollution of receiving environments (2). This recently-developed approach has not yet been incorporated into any community management programs.

Substantial barriers to the successful implementation of a performance-based code exist. Performance standards must be established for prescriptive system designs already in use. Additional performance standards must be established for system designs not addressed by current regulations.

A key element for the successful use of innovative system designs is the provision of adequate maintenance and monitoring. In many jurisdictions, resources to meet this need are lacking or are severely limited, in both the private and public sectors. The identification and development of management resources must be addressed and funding strategies must be developed.

Anthony Smithson, individual sewage program coordinator for the Lake County (IL) Health Department, with twenty years experience in the onsite wastewater field, expressed some of the concerns regulators have about the implementation of performance-based standards (12). Regulators operate within a political and economic environment that cannot be ignored. While performance-based codes provide flexibility and opportunities for creative system design, they may also lend to potential abuse in the absence of well-defined standards and provisions for consistent application and enforcement. A performance-based approach increases the responsibility of all involved parties, the site evaluator, the system designer, the installer, the maintenance provider, and the regulator. Prescriptive codes provide a structure necessary to deal with the practical realities of onsite wastewater regulation. If performance-based standards are used, they must be merged with improved prescriptive standards into an integrated program approach.

Recommendation

A performance-based approach to onsite wastewater management offers the promise of improved onsite system performance and treatment effectiveness, thereby providing greater protection of public health and environmental quality, and, at the same time, greater opportunities for development through the availability of innovative treatment options to overcome site limitations. Therefore, performance-based standards may actually allow development in areas that currently will not be developed using prescriptive standards. Before this approach can be realized, issues related to operation and maintiance must be addressed and resolved. Unless this is done, it is not reasonable to expect that a regulatory onsite wastewater management program based on performance standards can be successfully implemented at this time.

The Department should assess the need and present level of support for the development of a comprehensive, long-range onsite wastewater management plan, a coherent, integrated strategy addressing all essential aspects of the development and implementation of a regulatory program utilizing both prescriptive and performance-based standards. The plan should identify:

- training needs of all involved parties.
- existing resources for onsite system research and training.
- existing and potential resources (public and private) for providing onsite system maintenance and monitoring.
- funding strategies for development of training programs, certification/licensing programs, and onsite system maintenance/management programs.
- septage management needs and resources.
- enforcement strategies and resources.

If undertaken, the development of the plan must be a cooperative effort, with input from all areas of the onsite wastewater community, including system installers, system and component manufacturers, service providers, sewage management districts, local officials, developers, environmental groups, regulators, and others.

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H. Issue: Defining and Measuring System Failure, Long Term Acceptance Rate and Loading Rate, and Soil Classification

Onsite system failure can be characterized either as treatment failure or as hydraulic failure. Treatment failure may occur in the absence of hydraulic failure, but sound hydraulic performance of the system is essential to effective wastewater treatment. Defining and measuring treatment failure has been discussed in depth in other sections of this report. This section addresses hydraulic failure, contributing factors, evaluation, and prevention.

Hydraulic failure occurs when the rate of wastewater flowing into the system exceeds the rate at which wastewater infiltrates into the soil. When hydraulic failure occurs, wastewater is discharged to the ground surface or backs up into plumbing fixtures. A common cause of hydraulic failure is hydraulic overload, which can result from excessive water use by system users or because of leaking plumbing fixtures. Hydraulic failure may also occur where surface water flow is directed into the soil absorption area, roof gutters or paved areas direct their discharge into the soil absorption area, or lawn watering or irrigation from sprinkler systems installed on or near the absorption area add additional water to the soil.

Hydraulic failure can occur as a result of an inaccurate evaluation of soil characteristics, leading to an inaccurate estimation of the soil permeability and of the design loading rate. Poor construction practices (soil compaction, smearing of the trench sidewalls during excavation, use of mineral aggregates containing substantial amounts of fine particles, etc.) may cause hydraulic failure. Inadequate system maintenance, such as neglecting the need to pump out the septic tank, can also lead to system failure.

In addition to factors related to system siting, construction, use conditions, and maintenance, hydraulic performance is closely related to system design factors such as the long-term acceptance rate (LTAR), loading rate, soil permeability, and the depth of unsaturated soil beneath the infiltrative surface. The long-term acceptance rate is the rate at which a sewage treatment system will continuously accept effluent dependent upon the soil, biomat (clogging mat or crust), and effluent characteristics (3). The LTAR is the basis for the loading rates used for system design. The design loading rate is the rate at which effluent is to be applied to the infiltrative surface, usually expressed in gallons per day per square feet of infiltrative surface bottom area. Loading rate values are a function of soil texture and structure, and of the hydraulic conductivity of the clogging mat. The depth of unsaturated soil beneath the infiltrative surface (vertical offset to seasonal saturation or to a restrictive horizon) may affect the hydraulic gradient influencing the long-term acceptance rate.

Current Approach

Regulation 61-56 (15) does not include provisions for monitoring surface water or groundwater quality in order to assess system treatment effectiveness or impact to water quality as a result of onsite system use, and does not require that system hydraulic performance be routinely monitored by the department. At the time of installation of a new system and before the system is approved for use, an inspection by the department ensures that the system has been constructed in compliance with permit requirements and with Regulation 61-56 and applicable standards. Renewable operating permits are not required. In the event that system failure occurs, the most common means by which the department becomes aware of the failure is by receipt of a complaint (most complaints reporting system failures are made by nearby residents), by notification and request for assistance by the owner or occupant (or by a contractor the owner has asked to perform a repair), or as a result of a wastewater survey conducted by the department.

In cases where a complaint or a request for assistance is made, the department conducts an onsite inspection to determine the system status, to identify the cause of failure, and to determine feasible methods of repair. The property owner is informed that the system failure must be corrected within a specified time period. Follow-up inspections are made as needed to provide assistance and to ensure that the system has been repaired and is no longer malfunctioning.

Wastewater surveys are conducted periodically by the department to monitor program quality, to measure the performance of systems of a given age range or design category, or to assess sewage treatment needs in communities. These surveys have a common goal, to reduce system failures and their impact through improvements in program implementation (including site evaluation and permitting practices), onsite system design or placement criteria, or the assessment of communities (18) in need of assistance because of inadequate provisions for sewage treatment (absence of treatment systems, or existing systems which are failing and cannot feasibly be repaired).

Program surveys are designed and performed in order to evaluate critical aspects of program implementation by staff working in the district and county environmental health offices. Areas evaluated by survey administrative and field reviews include the quality of documentation, site evaluation, and system siting and design. Survey field inspections performed onsite include soil borings to determine the degree to which soil conditions have been correctly evaluated and design loading rates and other system specifications have been appropriately defined. Field identification of soil texture and structure classes and assignment of corresponding loading rates are defined by department standard (14). Loading rates defined in the standard are consistent with EPA recommendations (21) and are generally in agreement with those used in Wisconsin (19) and other states. Program surveys help to ensure that the loading rate standard is correctly and consistently implemented when site evaluations are performed. The department has recently undertaken the development of a staff standardization program in order to promote consistent and correct application of department procedures and standards related to onsite wastewater management. As Richard Otis has stated, "Failures of systems to perform are not due to inherent flaws in system concepts, but to their inappropriate application or operation. This occurs primarily because regulatory control is absent or not enforced. If onsite treatment systems are to be effective, a strong regulatory framework is necessary."(9)

System performance surveys are conducted in order to evaluate the degree to which systems are adequately functioning. In 1995, the department conducted a survey of five-year-old conventional and modified conventional systems, representing system designs most commonly used in the state (16). A total of 649 systems were examined during the first four months of 1995. During this period, actual rainfall amounts met or exceeded the normal for the period, which allowed for examination of the systems under high stress conditions. Of the 649 systems examined, there were 47 systems (7.2 percent) that were characterized as malfunctioning. This number includes systems which were discharging to the ground surface, backing up into the building, discharging via "straight pipe", or which showed evidence of prior system repair or signs of periodic or seasonal failure. Future system performance surveys are planned in order to evaluate the status of systems which have been in use for longer periods.

In addition to survey activities to examine and address system failures, the department has investigated methods for pretreatment of septic tank effluent (prior to discharge to soil absorption systems) to repair failing systems on existing sites where soil conditions do not meet current requirements. Research has indicated that improved effluent quality through pretreatment may have a positive effect on the rate at which wastewater moves into the soil (10,11,20), and may enhance the hydraulic performance of systems on poor sites.

On two existing failing sites, rock/plant filter (constructed wetlands) systems were installed and monitored. Analysis of filter influent and effluent samples indicated substantial improvement in wastewater quality. The department is now assisting regional Resource and Conservation Council offices with a project, under the direction of the USDA Natural Resources Conservation Service, designed to promote this use of rock/plant filters through the installation of six to eight systems in different areas of the state. The department is also conducting a project to install and monitor two peat biofilter systems on sites with failing systems at Lake Murray. Use of methods such as these may help to improve the performance of failing systems on sites where conventional methods of repair are not feasible.

Providing homeowners with basic information about onsite systems may help to reduce the occurrence of system failures. The department has developed informational materials (17) which are given to system owners when permits are issued, and distributed at public meetings. The materials provide information about how septic systems work and explain steps the homeowner can take to improve system performance and longevity.

Concern

System failures resulting in the discharge of wastewater to the ground surface or backing up into plumbing fixtures creates unsanitary conditions and hazards to public health and to the environment. If not promptly and properly corrected, system failures may result in the direct discharge of sewage to surface waters through run-off or by the piping or ditching of wastewater to streams or other water bodies. When these conditions are not reported to or discovered by the department, sewage discharges may continue over long periods, contributing to the degradation of water quality. With continued development, increased numbers of onsite systems and system density may create a greater potential for environmental degradation resulting from system failures.

Regulation 61-56 does not specifically address management of system failures by requiring that failures are promptly reported and repaired. The regulation does not require routine inspections of onsite systems to determine system conditions and whether repairs or septic tank cleaning may be needed. Homeowners or contractors are not required to report system failures or repairs. Repair permits are not routinely required, so that in most parts of the state there is little regulatory control over how repairs to failing systems are performed, a condition which may lend to the use of repair methods aimed at effluent disposal with little regard for effluent treatment.

Discussion of Available Technical Information

The earliest scientific investigations into how onsite wastewater systems work were directed at determining the causes of system failure. Prior to the post-World-War-II housing boom, the use of septic systems was mainly restricted to sparsely populated rural areas, and system failures were not of great concern. During the housing boom, stimulated by the federal insurance of housing loans, new home construction out paced the construction of public sewer systems, and septic systems were installed in more densely developed urban areas and housing developments, with little understanding of proper system siting or design. The large numbers of system failures which quickly resulted led to federally supported efforts to determine why system failure occurs.

Work undertaken at the Sanitary Engineering Research Laboratory (SERL) at the University of California-Berkeley, under the direction of Paul H. McGauhey and John H. Winneberger, helped to provide the foundation for understanding the mechanisms of soil clogging in soil absorption systems, and the role of the clogging mat in system performance and failure (5,6). Earlier examinations of soil clogging in agriculture and soil science research had identified a decline in infiltration rates in soils due to the development of a crust or biomat at the infiltrative surface, caused by microbial growth processes and byproducts, swelling and disaggregation of soil colloids, migration of fines, and other processes. SERL researchers further investigated elements thought to contribute to clogging mat development in soil absorption systems, including soil pore clogging by suspended solids, by slimes and other byproducts of microbial processes, and by ferrous sulfide deposition, and examined the influences of these processes on infiltration rates under aerobic and anaerobic conditions, and with variations in wastewater application strategies and trench design. The results of these studies emphasized the importance of the infiltration rate through the clogging mat as a critical system design consideration, and led to numerous research efforts which evaluated clogging mat development phenomena, methods for controlling the rate of development and deterioration of the clogging mat, methods for determining values of the long-term acceptance rate and loading rate under various conditions, and system design strategies to overcome or compensate for infiltration limitations and to promote hydraulic performance for a wide range of application conditions (3,7).

Research conducted by the Small Scale Waste Management Project, University of Wisconsin-Madison, provided the basis for the design loading rates currently used. A study by Johannes Bouma (4) collected in-situ measurements of hydraulic conductivity and soil moisture potential in twelve soil disposal systems, examined the relationships between the infiltration rate of the clogging mat and the flow through soils of various textures, and developed design loading rates based on soil texture classes: Conductivity Type I (sands), Conductivity Type II (sandy loams, loams), Conductivity Type III (silt loams, some silty clay loams) and Conductivity Type IV (clays, some silty clay loams). The defined loading rate values assume a depth of three feet (90 cm) of unsaturated soil beneath the infiltrative surface. The presence of water table at shallower depths produces decreased hydraulic gradients and infiltration rates through the clogging mat.

Failure rates of onsite systems in Florida were examined through three independent analyses of repair data, two from counties (Sarasota and Marion) with large numbers of installations, and one of data collected statewide (13). Florida has required permits for repairs since 1992. Sarasota County began issuing repair permits in 1975. A survey of repair data examined ages of failed systems, and indicated three peaks, one at four years after installation, one after ten years, and a third larger peak after twenty-five years. The mean age of system failure was at eighteen years. These values do not indicate system life expectancy, since the repair data excluded older systems that had never failed. Marion County began issuing repair permits in 1992 when repair permits became mandatory in the state code. Marion County repair data includes listing the cause of failure. For systems which failed during the first five years of service, the predominant cause was hydraulic overload. After fifteen years of service, root clogging was the cause of failure in most cases. The average age of failed systems was 18.35 years. The analysis of statewide data indicated a mean age of failure at 18.53. The most frequently cited causes of failure were root clogging (41%), system age (16%), hydraulic overload (11%), undersized systems (9%), high water table (6%), grease (4%), leaking plumbing (2%), distribution box (2%), and vehicular traffic (2%). Hydraulic failures were most often involved in early system failures, and root clogging in older systems failures.

Long-term use of onsite systems necessitates that the repair of failures is an essential function of regulatory programs. A systematic method to evaluate the cause of failure and to identify appropriate repair solutions increases the effectiveness of efforts to manage system failure. Environmental health specialists in North Carolina, with the assistance of NC State University, have developed a "Failure Analysis Chart for Troubleshooting Septic Systems" (FACTSS) to address this need (1). The FACTSS flowchart outlines step-by-step procedures addressing each potential cause of failure and provides solution options to repair malfunctions based on the identification of causes of failure. The method outlines a nine-step process for troubleshooting and identifies twenty-three probable causes of failure. Homeowner interview forms and homeowner water use ratings are used to collect pertinent information. The method has been field-tested and refined.

The Virginia Department of Health has developed a training manual to provide environmental health specialists a systematic approach to the analysis of system failures and determination of appropriate repair options (2). The manual identifies and addresses possible causes of system failure which were also shown to be prevalent in Florida.

Efforts to prevent or minimize system failures must address the need to provide system maintenance. Traditionally, resources for onsite system maintenance are lacking or are severely limited, and maintenance has been left to the individual homeowner. Experience has shown that homeowners typically do not provide adequate maintenance, either because of lack of knowledge or lack of interest, and often fail to take any action until system failure occurs. The need for maintenance has been emphasized in numerous studies. Required maintenance for all onsite systems was recommended for incorporation into the regulation and management of onsite wastewater systems in Virginia in 1991 (22) and in Florida in 1993 (8). Onsite wastewater regulators in states bordering the Gulf of Mexico have recognized the need for mandatory inspection, maintenance and monitoring of all onsite wastewater systems in regions that impact shellfish harvesting areas (12).

In Washington, in 1994, amendments to the state regulation were adopted which include new requirements for operation, monitoring, and maintenance of all onsite systems. Among other things, the amendments require that local health officials initiate periodic monitoring of each system no later than January 1, 2000, including annual inspections of systems serving food service establishments. The Washington State Department of Health has published a guidance handbook for onsite system monitoring programs (23). The handbook discusses the goals and objectives of a monitoring program, outlines the benefits of a monitoring program, provides information to assist in the development and implementation of a monitoring program, explains essential program components, discusses funding strategies, and provides a description of established and developing programs in twelve locations in Washington, California, Ohio, and New York.

Recommendation

In order to minimize the occurrence and impacts of system failures, the Department should:

- Develop and implement a staff standardization program emphasizing site evaluation, system siting and design, and installation inspection procedures.
- Develop training programs for staff and contractors in proper system construction practices and the consequences of improper construction techniques.

- Develop a system failure analysis protocol to define procedures applicable to the inspection, analysis, and repair of failing systems. Provide training programs in failure analysis and repair for staff and contractors.

- Obtain information about system repairs to provide data necessary to assess the need for modifications to current design or siting standards.

- Identify potential resources, technical and financial, which may be developed to establish programs for routine maintenance of onsite systems.

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FIGURES

(References for Figures 2 through 11)

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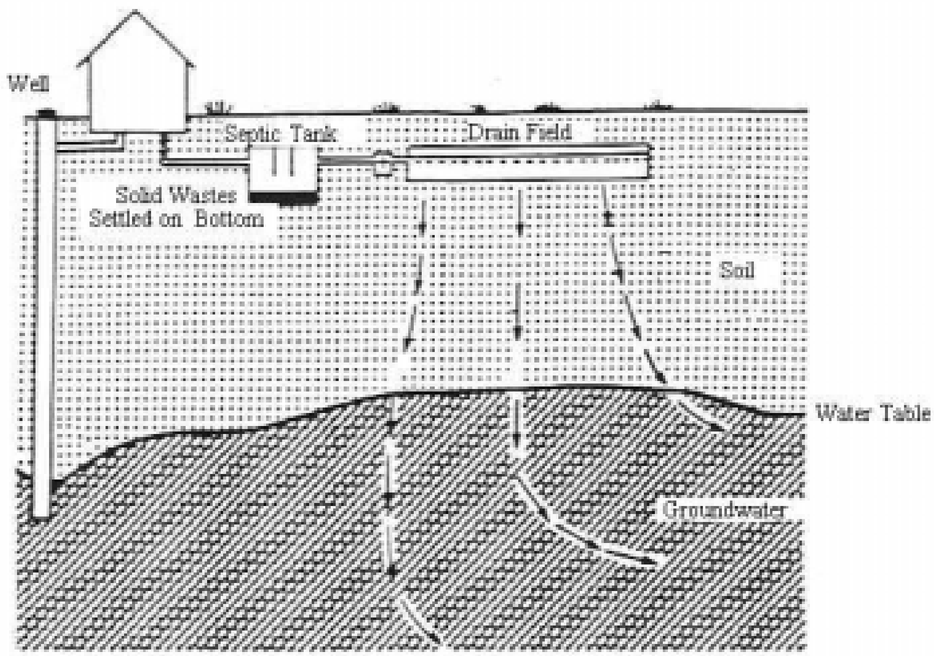
NOTE: Several of these references are compilations of results of studies at multiple locations. These locations at noted as separate data points on several graphs (e.g., #9c-1{site c-1}, 12-low {lower drain field}, etc.). Reference #13cs refers to continuously saturated and #13ss refers to seasonally saturated.

A Typical Septic System



(Modified from EPA Document Septic systems and Ground-Water Protection, An Executive's Guide FMPOG05 1986)

Figure 1

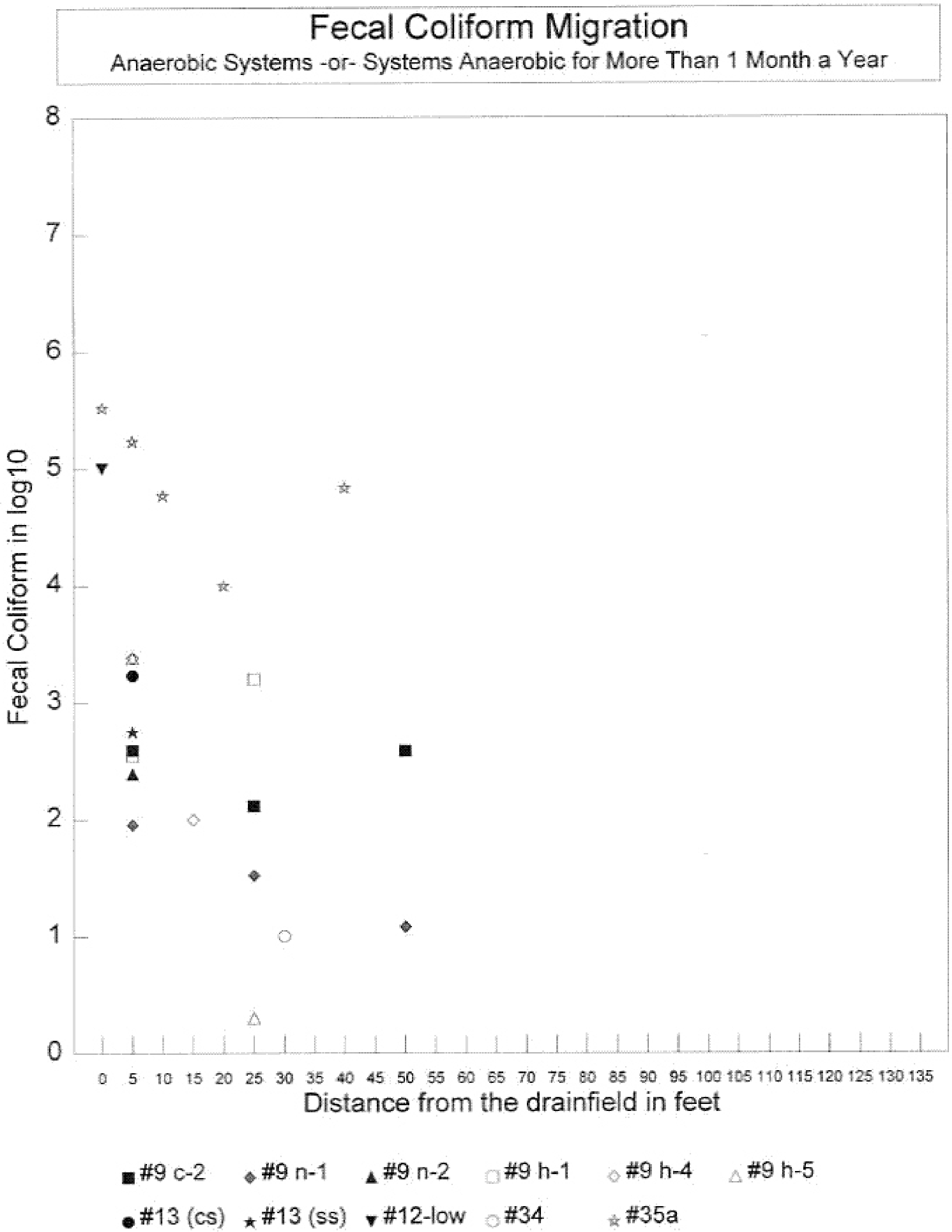
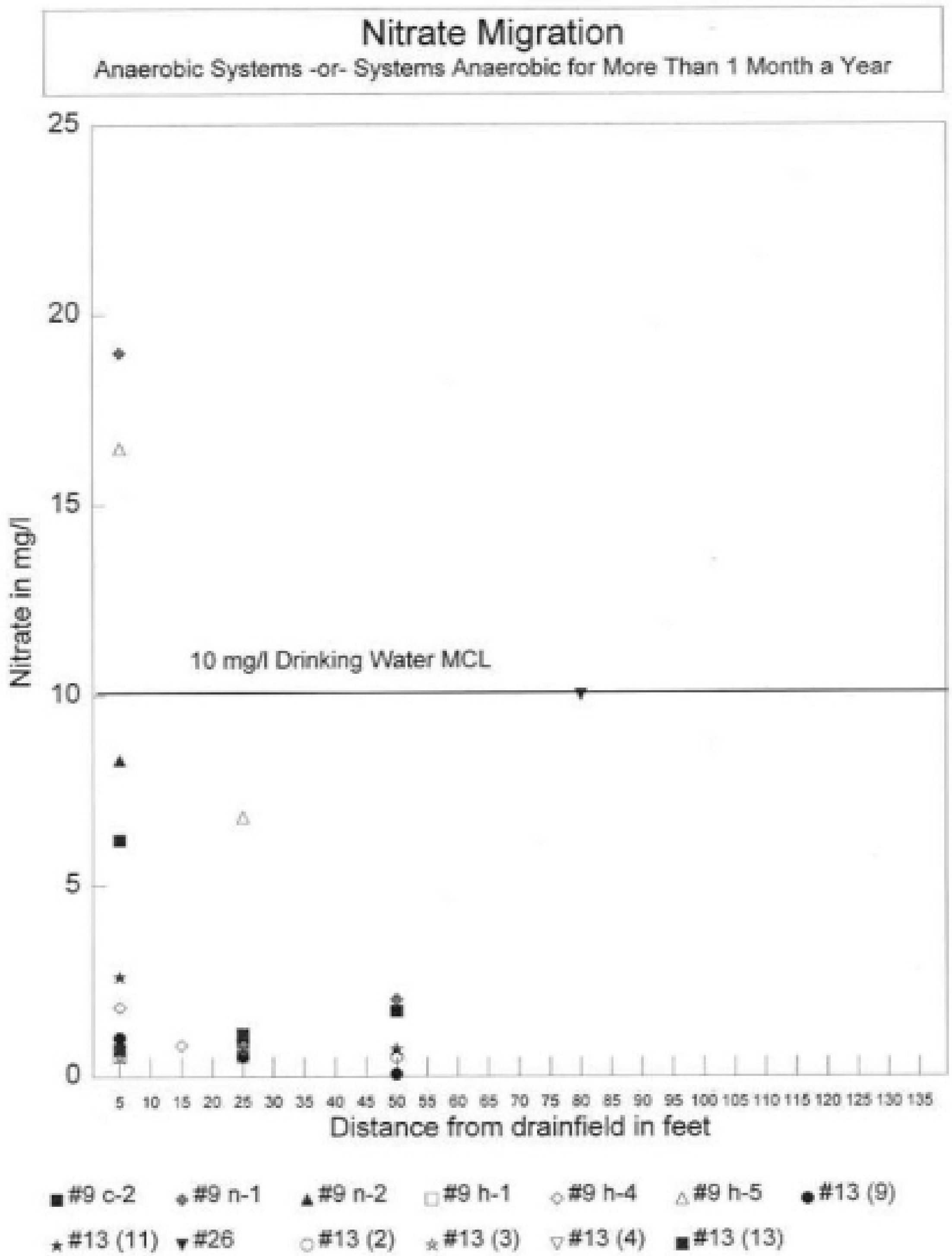

Fecal Coliform Migration
Anaerobic Systems -or- Systems Anaerobic for More Than 1 Month a Year
Fecal Coliform in log10
8
7
6
5
4
3
2
1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
Distance from the drainfield in feet
#9 c-2
#9 n-1
#9 n-2
#9 h-1
#9 h-4
#9 h-5
#13 (cs)
#13 (ss)
#12-low
#34
#35a

Figure 2



Nitrate Migration
Anaerobic Systems -or- Systems Anaerobic for More Than 1 Month a Year
25
20
15
10
5
0
Nitrate in mg/l
10 mg/l Drinking Water MCL
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
Distance from drainfield in feet
#9 c-2
#9 n-1
#9 n-2
#9 h-1
#9 h-4
#9 h-5
#13 (9)
#13 (11)
#26
#13 (2)
#13 (3)
#13 (4)
#13 (13)

Figure 3

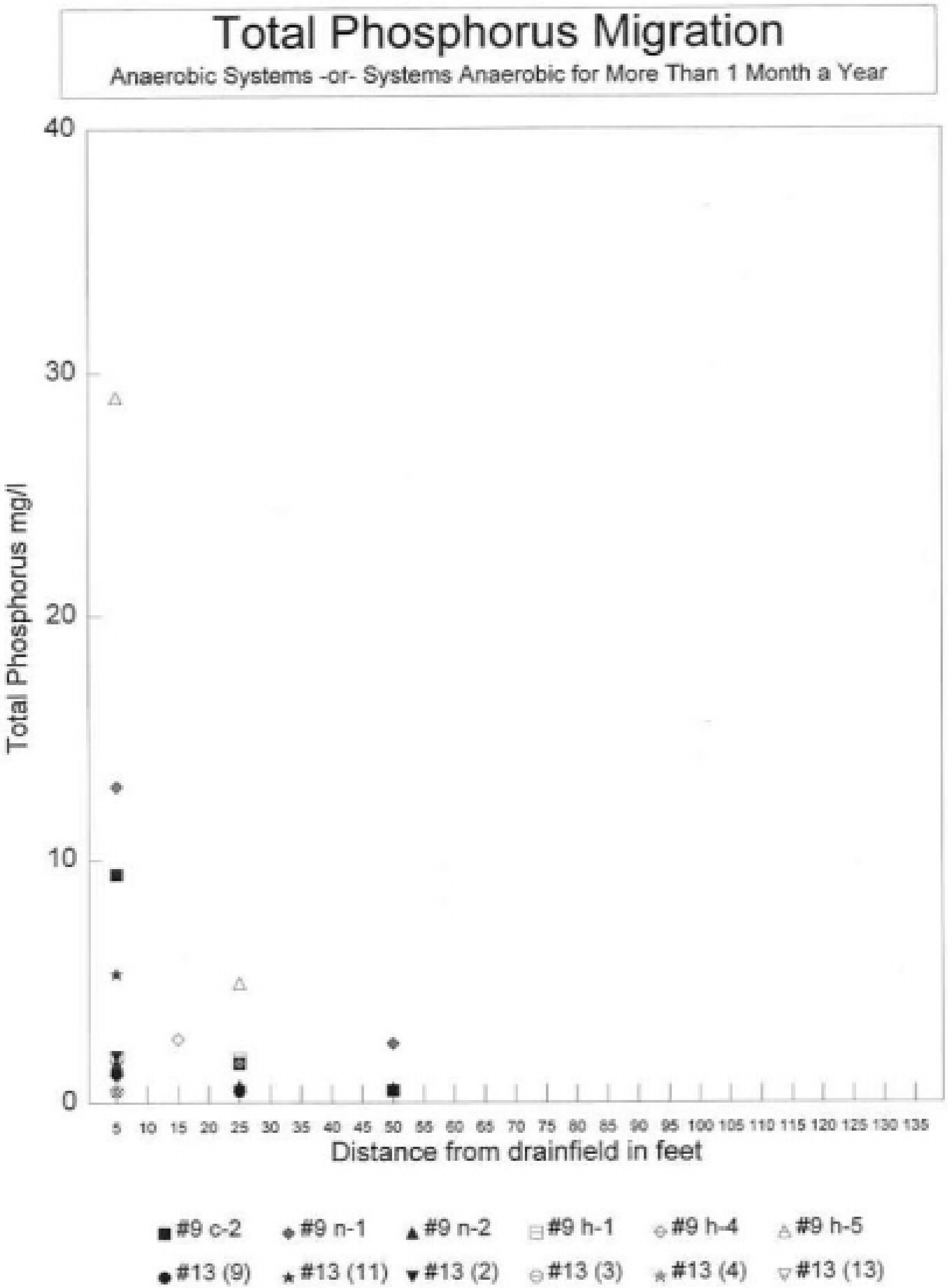

Total Phosphorus Migration
Anaerobic Systems -or- Systems Anaerobic for More Than 1 Month a Year
Total Phosphorus mg/l
0
10
20
30
40
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
Distance from drainfield in feet
#9 c-2
#9 n-1
#9 n-2
#9 h-1
#9 h-4
#9 h-5
#13 (9)
#13 (11)
#13 (2)
#13 (3)
#13 (4)
#13 (13)

Figure 4

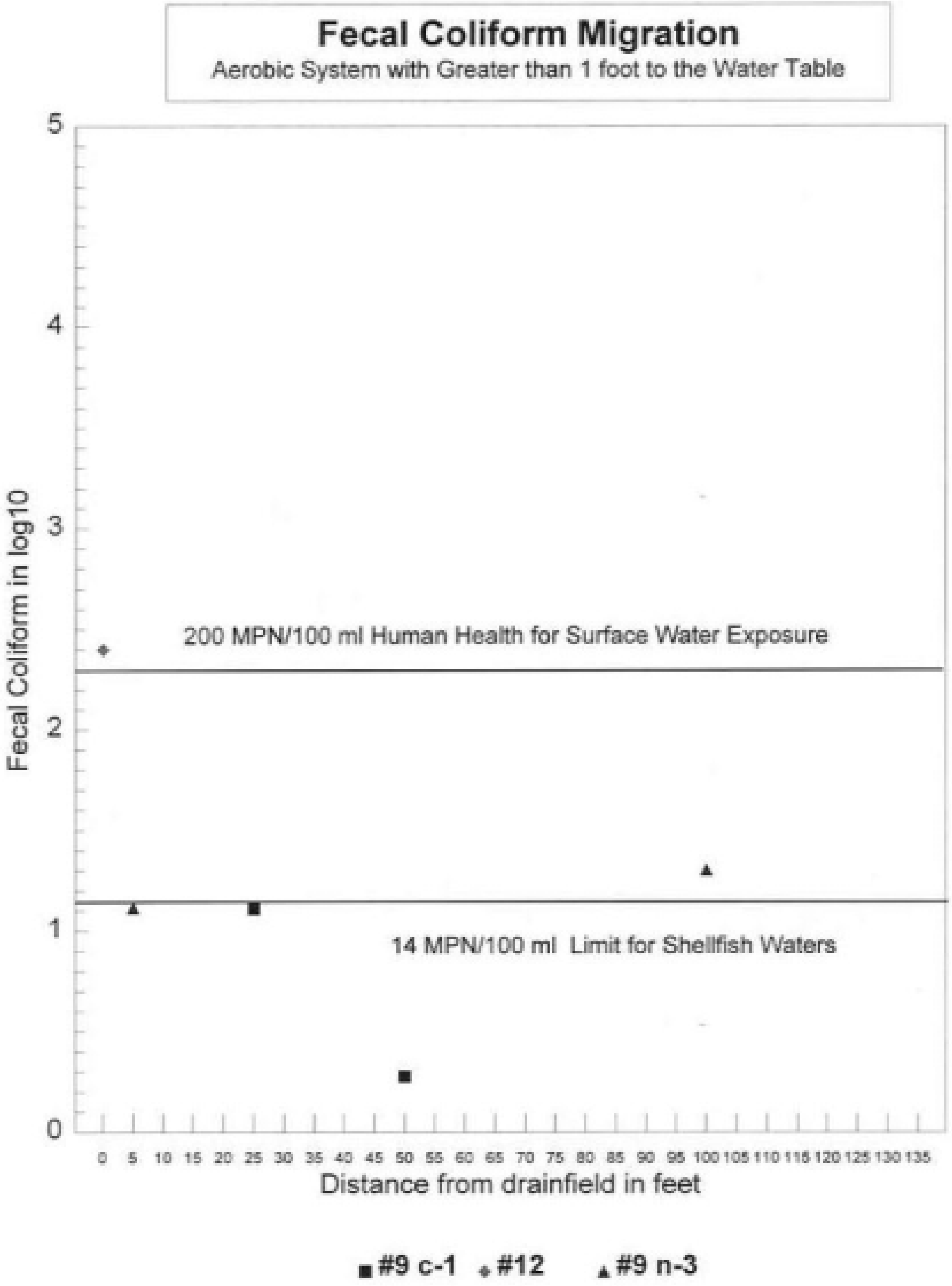

Fecal Coliform Migration
Aerobic System with Greater than 1 foot to the Water Table
200 MPN/100 ml Human Health for Surface Water Exposure
14 MPN/100 ml Limit for Shellfish Waters
Fecal Coliform in log10
Distance from drainfield in feet
0
1
2
3
4
5
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
#9 c-1
#12
#9 n-3

Figure 5

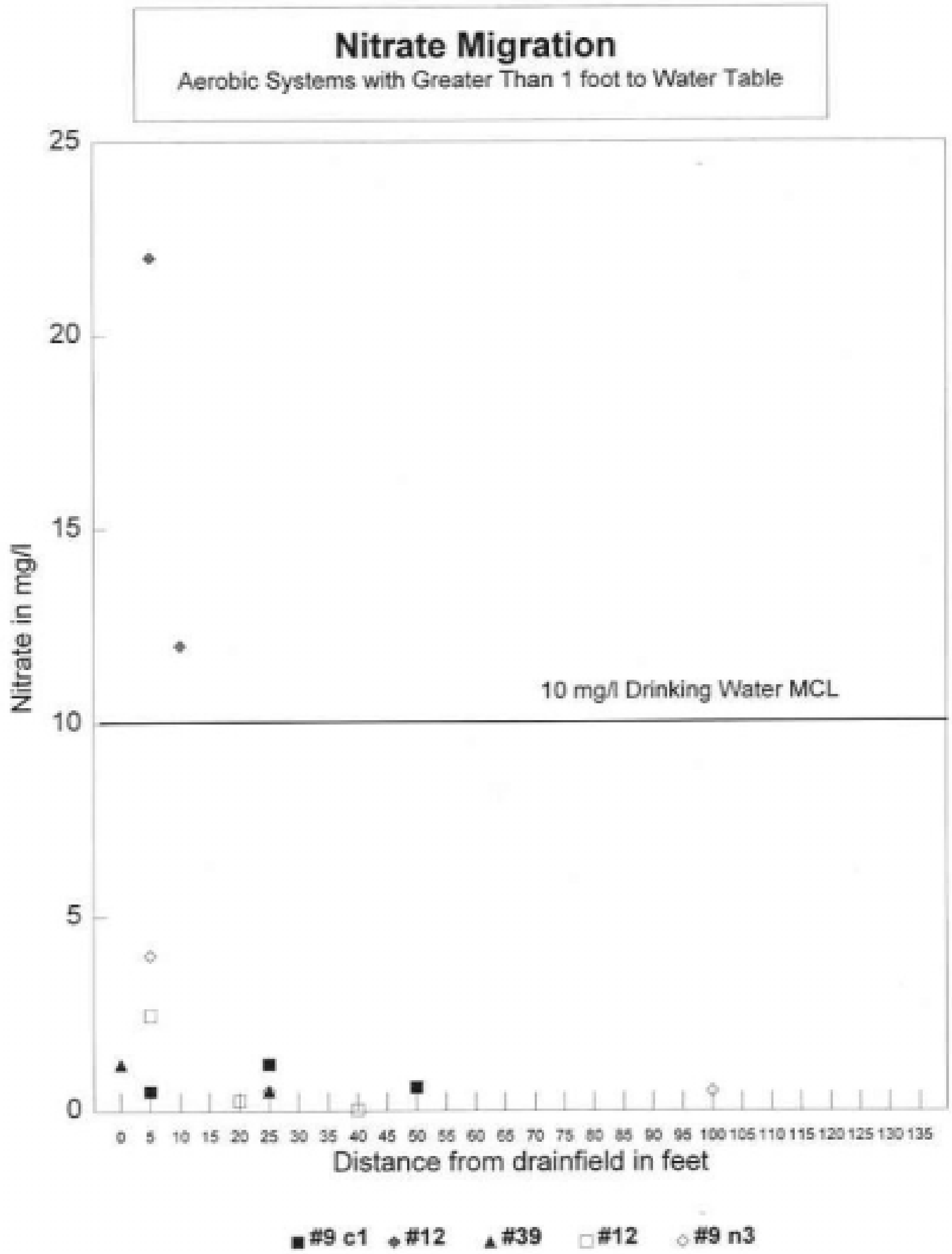
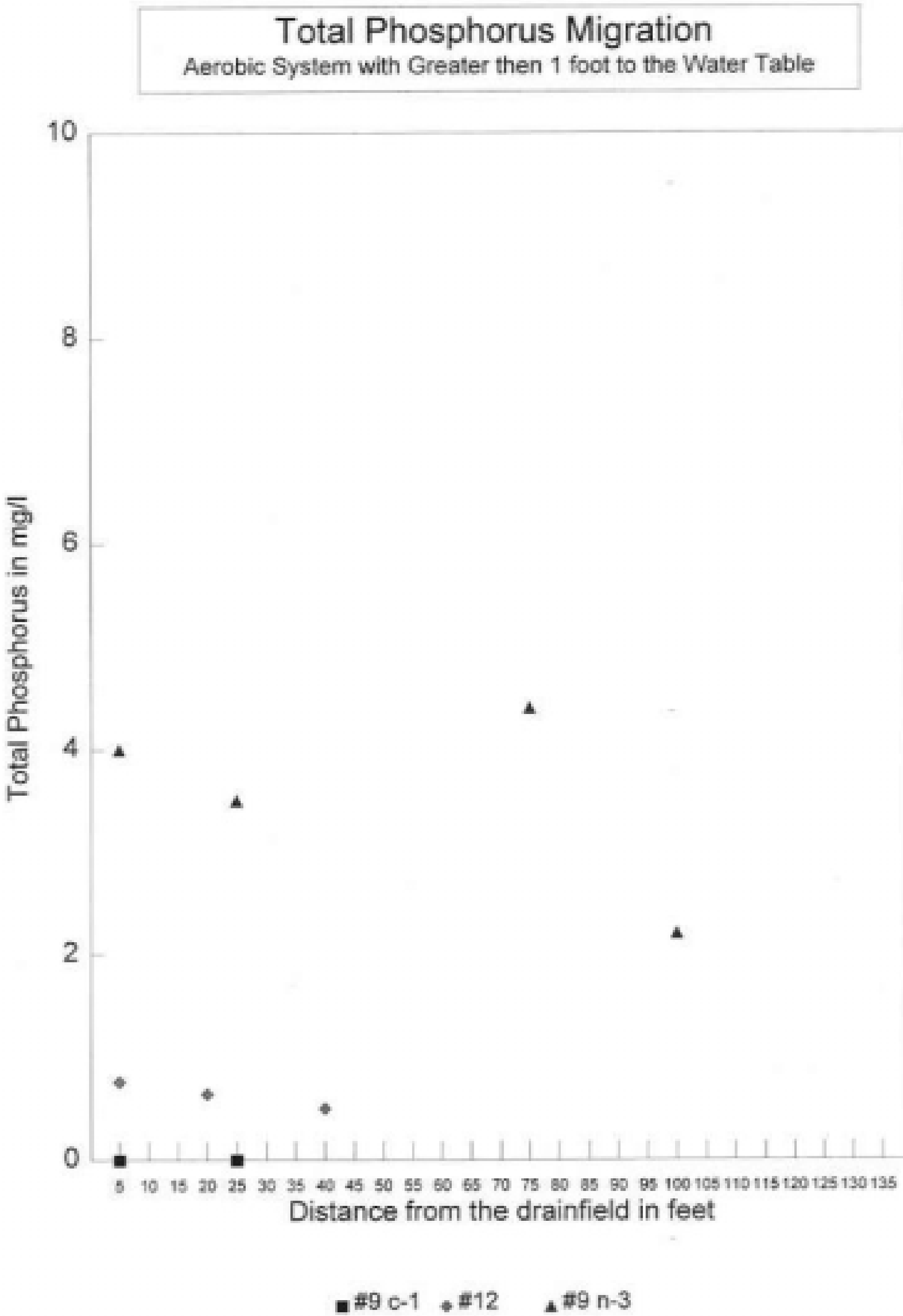
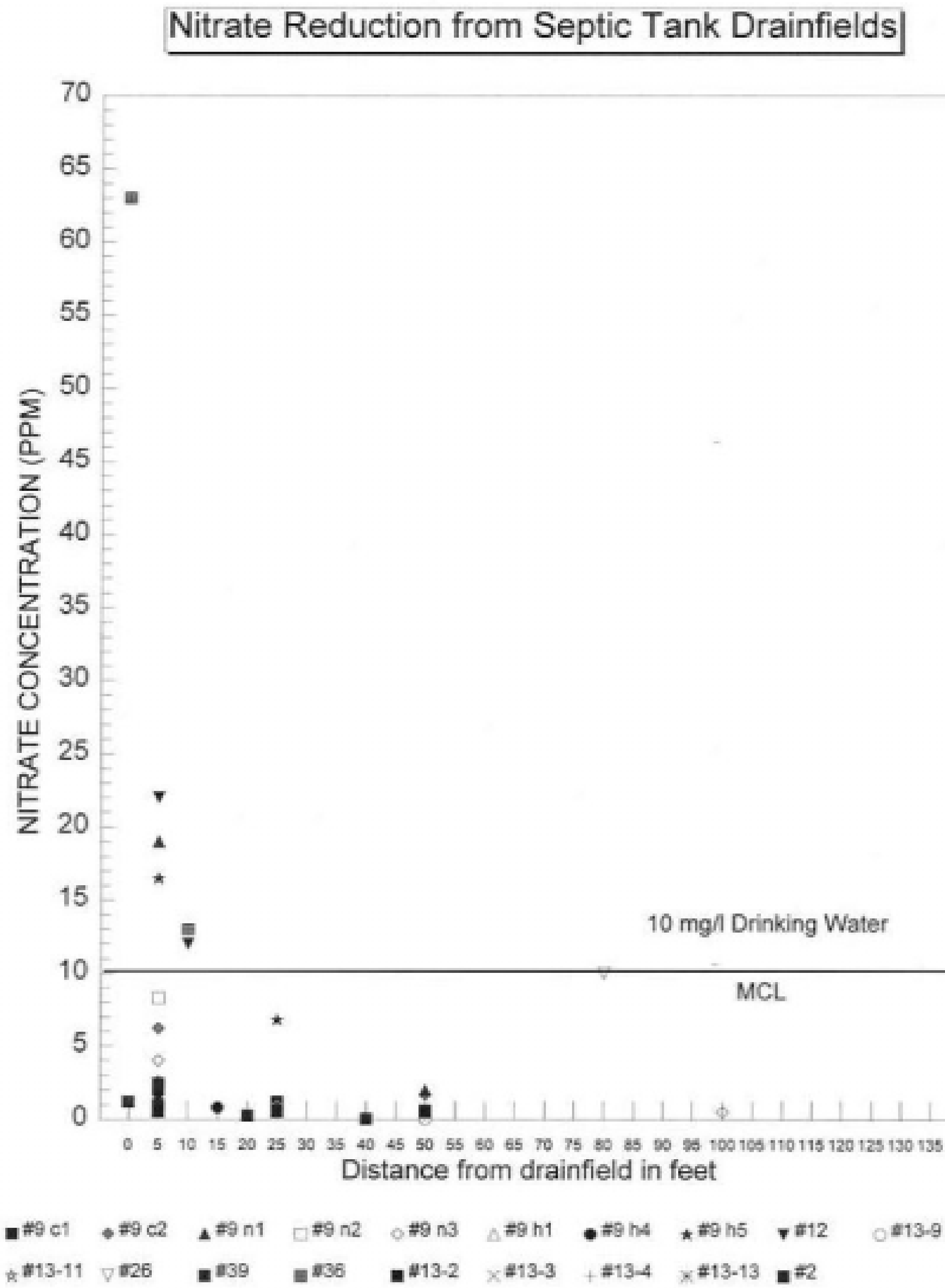

Nitrate Migration
Aerobic Systems with Greater Than 1 foot to Water Table
Nitrate in mg/l
10 mg/l Drinking Water MCL
Distance from drainfield in feet
#9 c1
#12
#39
#12
#9 n3

Figure 6



Total Phosphorus Migration
Aerobic System with Greater then 1 foot to the Water Table
Total Phosphorus in mg/l
Distance from the drainfield in feet
0
2
4
6
8
10
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
#9 c-1
#12
#9 n-3

Figure 7



Nitrate Reduction from Septic Tank Drainfields
NITRATE CONCENTRATION (PPM)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10 mg/l Drinking Water
MCL
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
Distance from drainfield in feet
#9 c1
#9 c2
#9 n1
#9 n2
#9 n3
#9 h1
#9 h4
#9 h5
#12
#13-9
#13-11
#26
#39
#36
#13-2
#13-3
#13-4
#13-13
#2

Figure 8

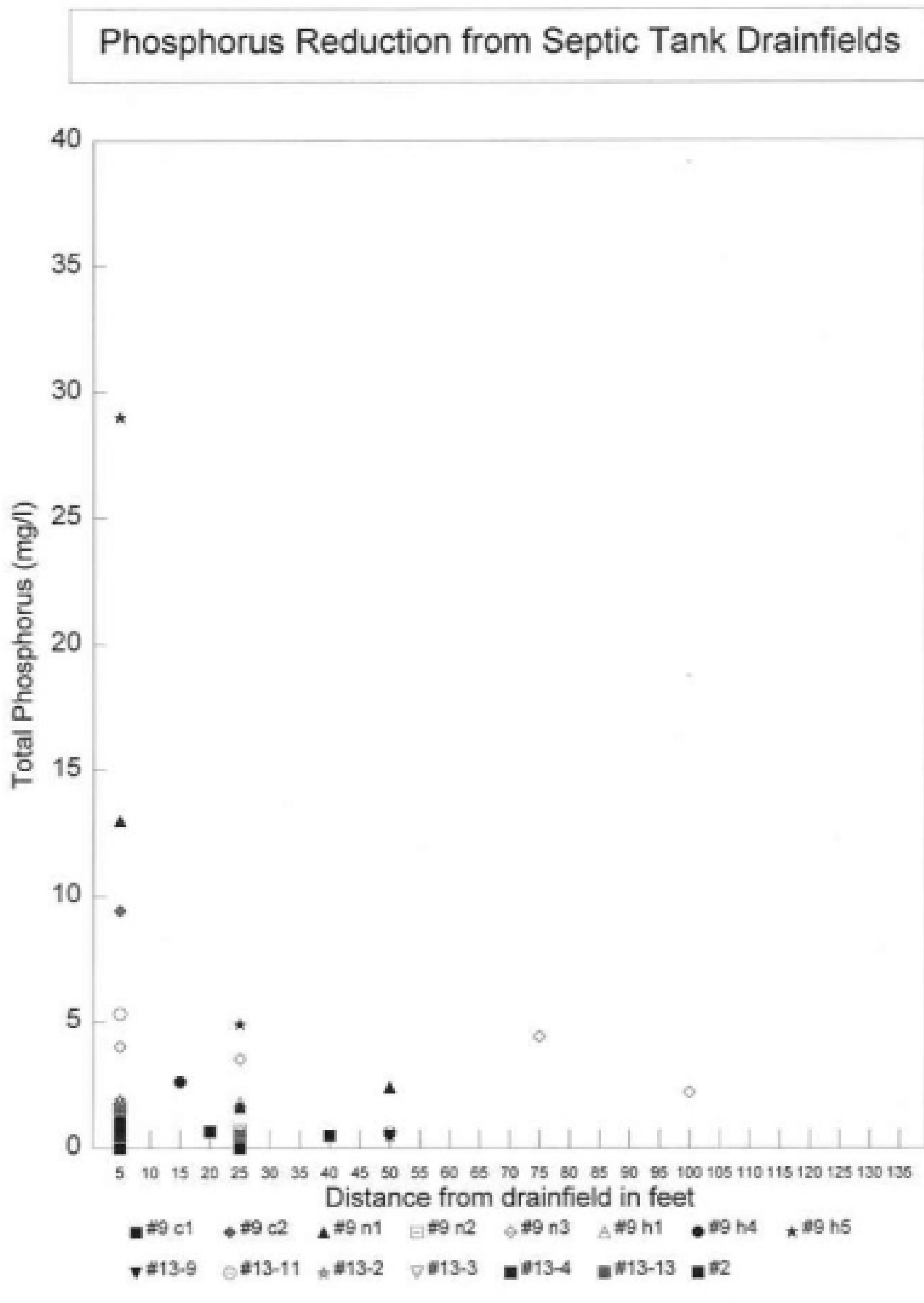

Phosphorus Reduction from Septic Tank Drainfields
Total Phosphorus (mg/l)
Distance from drainfield in feet
#9 c1
#9 c2
#9 n1
#9 n2
#9 n3
#9 h1
#9 h4
#9 h5
#13-9
#13-11
#13-2
#13-3
#13-4
#13-13
#2

Figure 9

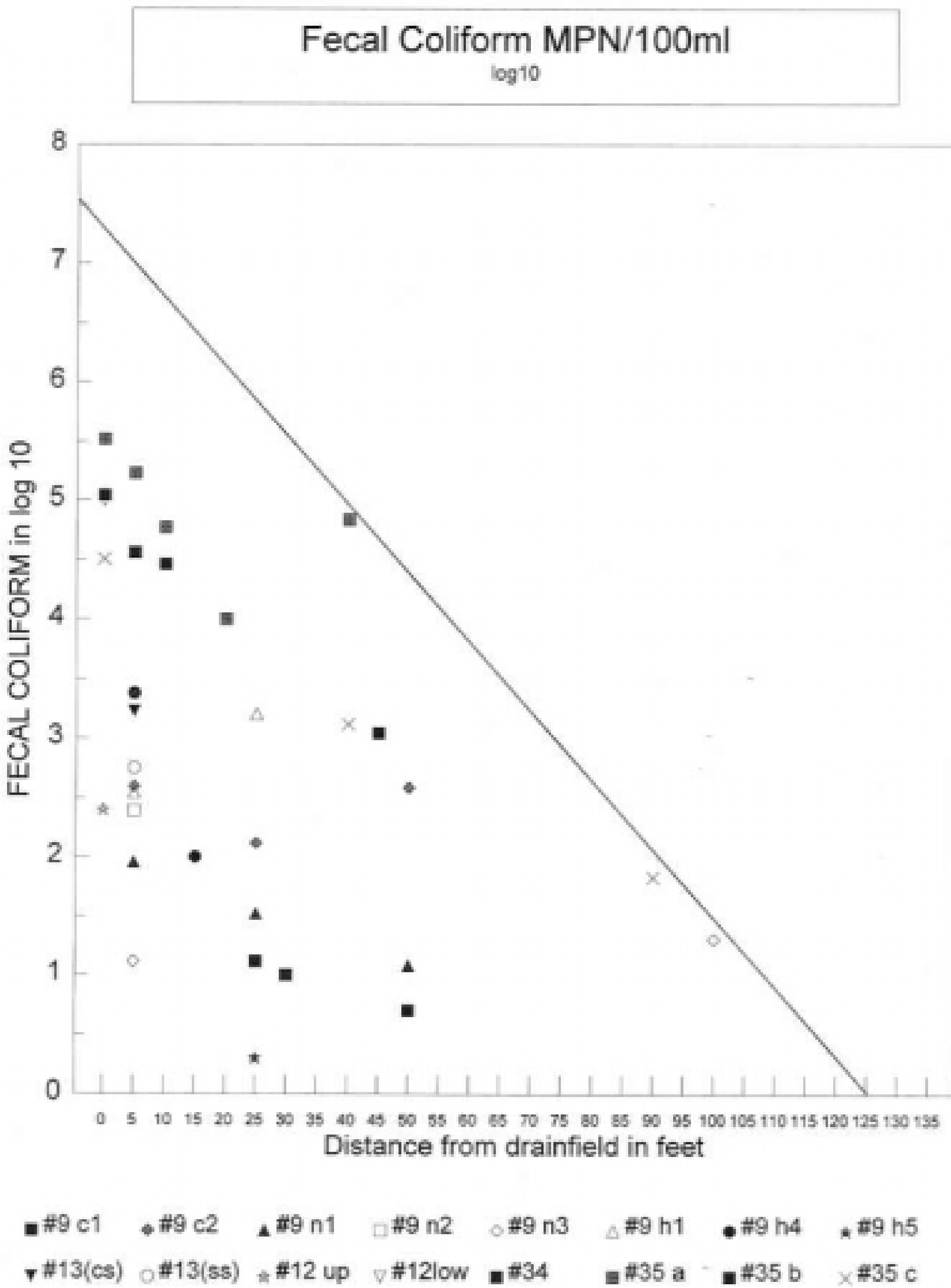

Fecal Coliform MPN/100ml
log10
FECAL COLIFORM in log 10
Distance from drainfield in feet
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
0 1 2 3 4 5 6 7 8
#9 c1
#9 c2
#9 n1
#9 n2
#9 n3
#9 h1
#9 h4
#9 h5
#13(cs)
#13(ss)
#12 up
#12low
#34
#35 a
#35 b
#35 c

Figure 10

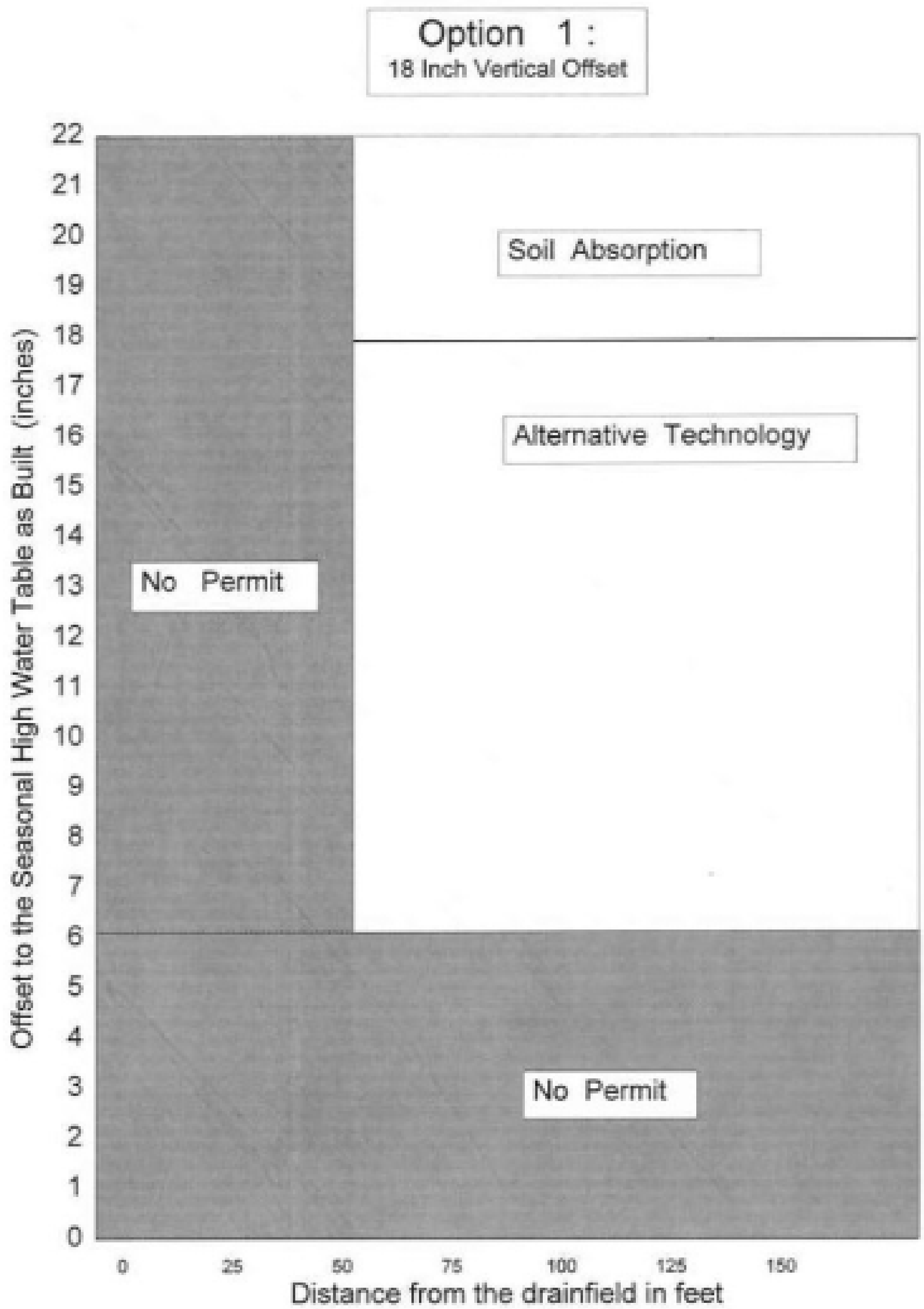

Option 1 :
18 Inch Vertical Offset
Soil Absorption
Alternative Technology
No Permit
No Permit
Offset to the Seasonal High Water Table as Built (inches)
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
25
50
75
100
125
150
Distance from the drainfield in feet

Figure 11

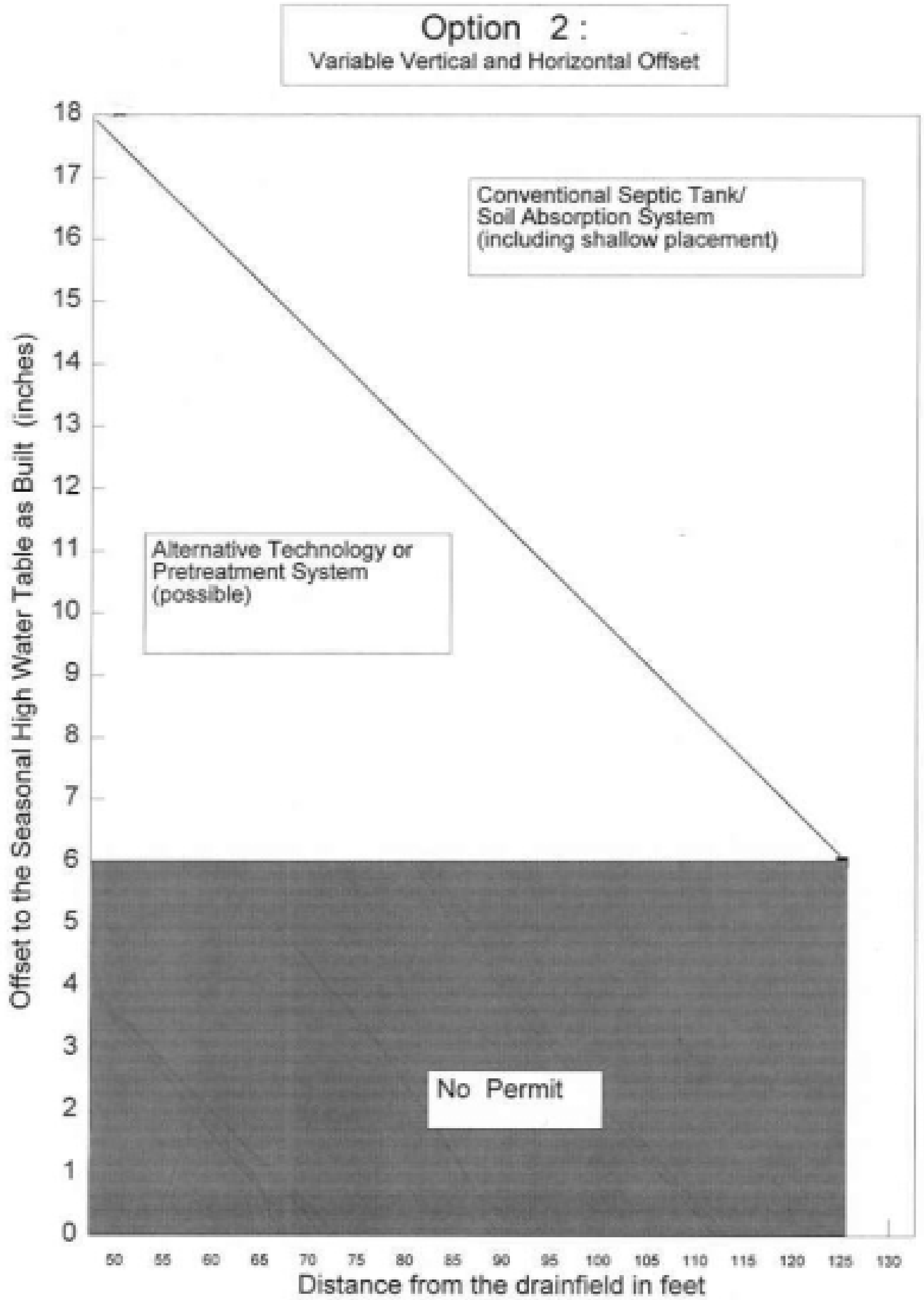

Option 2 :
Variable Vertical and Horizontal Offset
Conventional Septic Tank/
Soil Absorption System
(including shallow placement)
Alternative Technology or
Pretreatment System
(possible)
No Permit
Offset to the Seasonal High Water Table as Built (inches)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130
Distance from the drainfield in feet

Figure 12